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ABSTRACT

This publication provides information about present uses of solar energy for space, water, and swimming pool heating that are practical for the San Francisco Bay area. It attempts to provide interested persons with the information needed to make decisions regarding installations of solar heating systems. The point of view taken is that any structure can be retrofitted with a solar heating system. Chapter titles include: (1) Solar Basics; (2) Energy Estimating and Conservation; (3) Solar Prospecting; (4) Retrofit Systems; (5) Estimating Performance; (6) Solar Economics; (7) Getting Started; and (8) Further Information. Many different adaptations of both passive and active solar heating systems are diagrammed and explained. Installation tips and precautions are also included. Worksheets are provided, along with completed examples, to aid in estimating the cost of installing solar heating systems. Additional sources of information are suggested to the interested reader. Even though this publication refers to the San Francisco area, the solar retrofitting information given applies almost anywhere. (MR)

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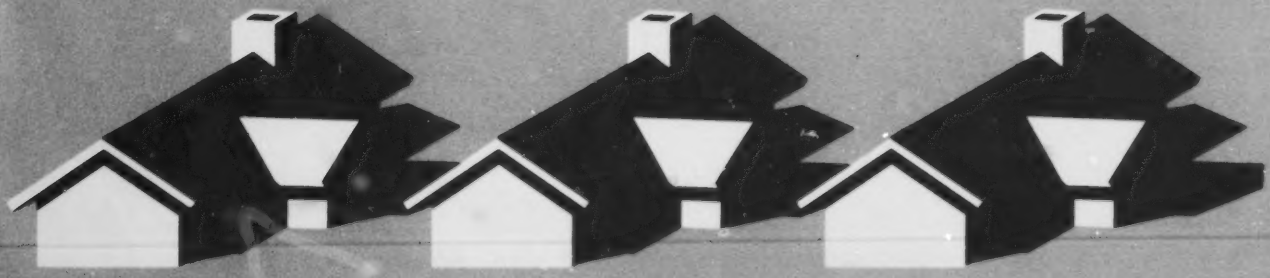

Solar for Your Present Home

Prepared for the California Energy Commission

San Francisco Bay Area Edition

Charles S. Barnaby
Philip Caesar
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Berkeley Solar Group

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Environ/Mental

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Introduction

Are you interested in solar energy, but feel you lack enough information to make a realistic decision about using it? There already are many designers, contractors, and equipment suppliers ready to help you. However, in order to effectively use their services, participate in the choice and design of your solar energy system, or build a system yourself, you must first have a good idea of what you want to do. That's what this book is for. We discuss everything from energy conservation to the pros and cons of the various solar applications feasible in the San Francisco Bay Area. Even if you decide not to install some sort of solar energy system, the energy-saving measures you will read about make this book well worth your while.

Although much of the information in this book is applicable to almost any climate or region, special attention is given to the requirements of the San Francisco Bay Area. As shown on the accompanying map, we use this name to cover the nine counties of San Francisco, Marin, Sonoma, Napa, Solano, Contra Costa, Alameda, Santa Clara, and San Mateo. This region generally has better than average potential for using solar energy because of its moderate winters and ample sunshine throughout the year. Yet the region also has wide variations in climate, so even the specific Bay Area information is useful in many other parts of California and other states as well.

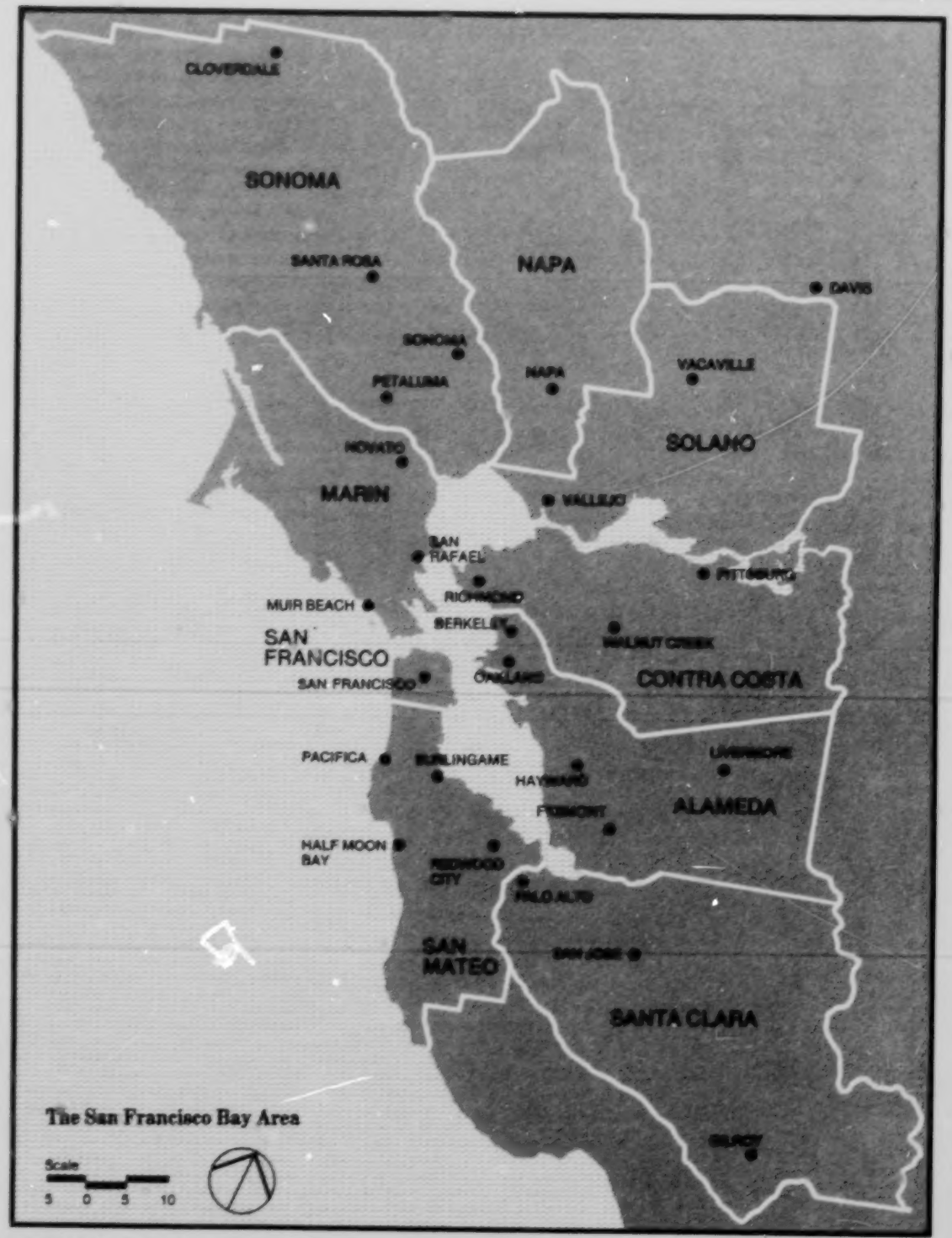
Which uses of solar energy does the book cover?

We are concerned with uses of solar energy that are *practical right now*. This means we will be discussing the use of solar energy as a *heat* source for water heating, space heating, and swimming pool heating. We also will be concentrating on retrofit applications – using solar energy in *existing* houses.

Solar energy has been used primarily in new construction. Unless we convert our existing buildings to solar, however, the benefits of solar heating will be unnecessarily slow in coming and limited to only a small fraction of the population. This is why special attention is now being given to retrofits. At the same time, the information in this book will be helpful to you if you are planning a new home or evaluating a home for potential purchase.

Solar retrofitting is not limited to homes. Businesses that use hot water, such as laundries and carwashes, can expect substantial savings from solar water heating. Apartment buildings are also prime candidates for solar water heating. Even renters can increase their use of solar energy to some degree without making permanent alterations. In fact, just about any structure should be regarded as a potential retrofit.

Some buildings, of course, have better orientation to the sun or more adaptable heating equipment than others. Then again, in other cases, there is no reasonable way to use the sun. However, there are no hard and fast rules. You must do a careful survey in order to determine how suitable your house or building is for solar retrofitting.



The San Francisco Bay Area

Why retrofit now?

It's natural to assume that solar equipment will become drastically cheaper in the next few years, just as pocket calculators have in the last few. However, solar energy systems consist primarily of ordinary building materials and plumbing and heating equipment put together in new ways. So, unfortunately, the total price is not likely to come down substantially, if at all. However, California state solar tax credits are available and they have the effect of reducing the total cost. Federal tax credits should be on the books soon.

As we mentioned above, contractors, designers, and suppliers specializing in solar energy are already in business around the Bay Area. This means that you can now consider using solar energy even if you have little technical and do-it-yourself experience. Since installing solar equipment is a large job in most cases, we recommend that you get professional help to make sure your project is successfully completed.

How to use this book

Because solar energy is a new subject for most people, we suggest you first look quickly through all the chapters in order to get a feel for the book's entire procedure. The chapters are arranged in a logical sequence, reflecting the process of planning a solar project. Starting on page 131, blank worksheets are provided to assist you where calculations are required. Cut them out, photocopy them if you want extras, and keep them handy as you proceed through the book. Sample, filled-out worksheets are included in the chapters.

The first six chapters of this book provide the information you need to make a reasonable decision about taking advantage of heat from the sun. Because every solar system is different and the components are varied, we have not included blueprints of actual systems. So after you choose a practical system, it still must be designed in detail and, of course, installed. Therefore, the final two chapters of the book discuss how to hire people to help you, how to evaluate and buy equipment, and how to locate further information. That will start you in the right direction to see your solar project through.

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Retrofit Examples

A booming solar energy industry existed in Florida, California, and parts of the Southwest during the 1930's and 1940's. As electricity, natural gas, and other fuels became readily available and dropped in price, the use of solar energy declined until only a handful of enthusiasts remained.

In the last few years all this has changed. Environmental concerns, rising fuel costs, and the possibility of fuel shortages have made solar energy attractive to manufacturers, architects and builders, and owners of homes and businesses. The current situation regarding the use of solar energy is something like this:

- Solar energy *works* for space heating (keeping the interior of your house warm), water heating (providing hot water for showers, clothes washing, etc.), and pool heating. The systems can be readily designed and the necessary hardware bought off-the-shelf. In some cases, solar energy systems can be used to cool your house, but they are not practical for generating electricity.
- You may not eliminate your gas and electric bill by using solar energy, but you can reduce it substantially.
- In many cases, the use of solar energy is justified purely on economic grounds, but there are important non-economic considerations as well, such as ecology and self-reliance.
- It's now technically feasible for *existing* homes and businesses, especially if the structure and the present heating system are suitable.

Let's start with three examples of San Francisco Bay Area homes that have been retrofitted for solar house heating or water heating. They will give you an idea of what it's like to have the sun at work in your home.

A solar water heater

In 1974, an old Victorian in Berkeley was renovated by the Farallones Institute to house projects demonstrating "ecological household management." One of their first projects, a solar water heater, has since provided over 95 percent of their hot water needs. Doug Daniels and Scott Matthews, the consultants who designed and built the system, chose materials such as copper and tempered glass for long life, rather than low initial cost. As a result the total cost was high, about $1100 for materials alone. However, the same do-it-yourself system sized for an average family's hot water use, rather than for numerous Institute staff and visitors, would cost only about half that amount.

If you take one of the Saturday tours of the Farallones house (see "Places to Visit," page 112), you'll see about 90 square feet of glass-covered black panels mounted on the south-facing roof of a small greenhouse addition. These panels, which look like the pictures of "solar houses" you've probably seen in newspapers and magazines, are called *flat-plate collectors*. They are the part of the system where solar energy is collected and turns into heat. There are three other parts as well: a 120-gallon glass-lined steel storage tank in the attic (well supported and braced to withstand earthquake activity), a 30-gallon back-up electric water heater in the kitchen, and the pipes that connect everything together.

City water comes into the system at about 60°F and cycles a number of times through the collector and the storage tank. Each pass the water makes through the collector, it heats up more. Eventually the temperature reaches 140°F to 160°F, comparable to what regular water heaters achieve. When a water tap is turned on, hot water flows out of the storage tank and through the back-up water heater before reaching the faucet. The system was designed this way so that if it doesn't heat the water sufficiently, the back-up heater is automatically activated and boosts the water to the desired temperature.

Figure 1-1: The flat-plate collectors at the Farallones Institute. The panels face south so they receive strong, midday sun. The storage tank for the system is in the attic of the house, above and behind the collectors.

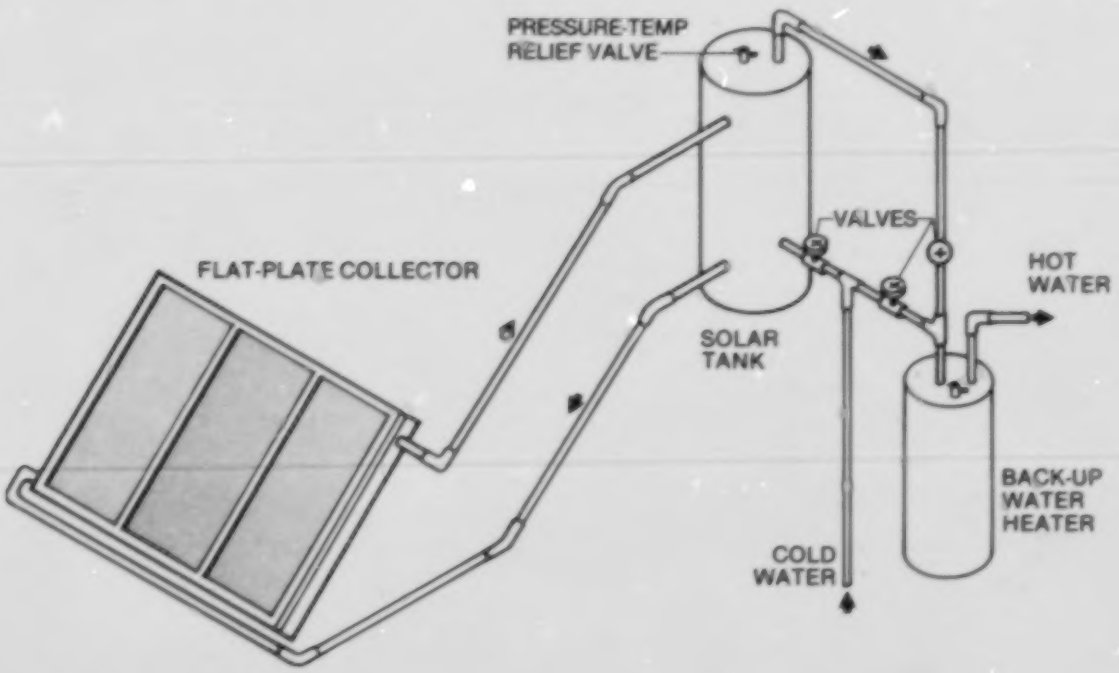

Figure 1-2: Schematic diagram of the Farallones water heater. Solar heated water rises from the collector into the tank causing the system to circulate naturally. No pump is required. This is called a *thermosiphon system*; it will be discussed in Chapter 4. The valves allow cold water to be fed directly to the back-up heater.

A house made for solar heating

When Klaus Heinemann bought his home in Sunnyvale, he had no idea that its radiant heating system, in which boiler-heated water is circulated through pipes in a concrete slab floor to heat the house, would turn out to be ideal for simple conversion to solar energy. His house also has a south-facing roof unobstructed by tall trees or neighboring homes. In 1975, he designed and installed a solar energy system that, like the Farallones system, heats water with flat-plate collectors. However, Heinemann's is a *dual* system. The collectors provide hot water both for bathing and other uses and for the radiant heating system. The self-financed system, which cost about $3000, provides about 70 percent of his family's total water heating and space heating needs.

The solar heating system also operates like the Farallones system, heating water by continuously circulating it between the collectors and the storage tank. In this case, the collectors are above the storage tank, so the water must be pumped. Since the volume of hot water required is considerably larger, the flat-plate collectors (made of aluminum in this case) cover about 350 square feet of the south-facing roof. The storage tank holds 1,000 gallons, enough to provide house heating through one sunless day. The tank is partially buried in the ground near the closet containing the gas-fired boiler for the radiant heating system. When heat is needed, the solar-heated water is pumped through the radiant floor slab. If the sun can't heat the water enough, the boiler (now the back-up) is turned on.

Figure 1-3: The Heinemann house. Two areas of flat-plate collector are mounted on the south-facing roof area. The storage tank is buried to the right of the house.

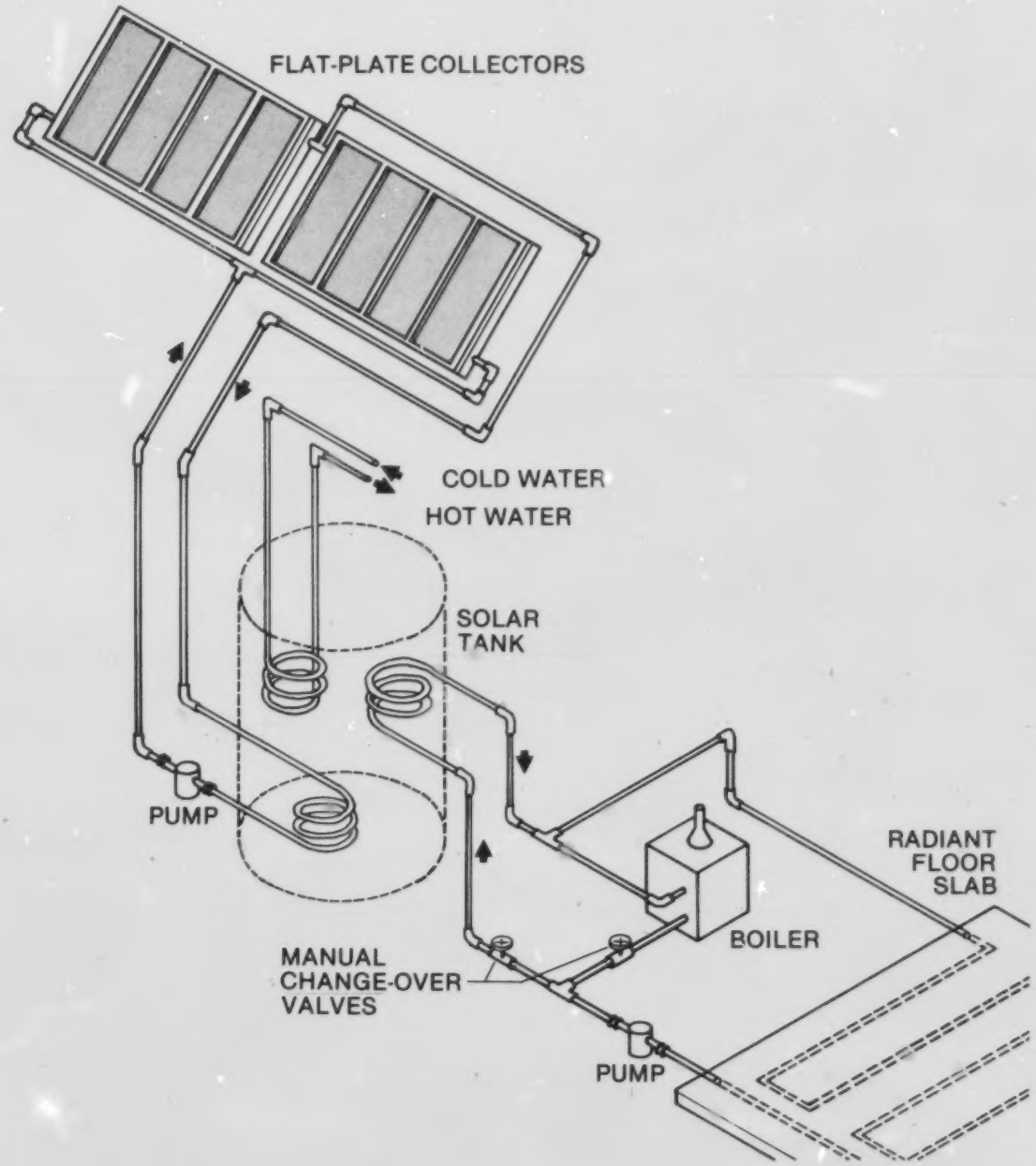

Figure 1-4: **Schematic of the Heinemann system. The water that circulates through the collectors heats the storage water via a coil. Heat for water and space heating is withdrawn via other coils. The coil for water heating acts as a preheater; solar heated water is fed to the gas water heater so it operates less frequently.**

A room addition doubles as a solar heater

The Jon Hammond home in Winters (near Davis) is a textbook example of how to incorporate solar energy into a renovation or addition. His retrofit has been a remarkably successful one, providing about 90 percent of the house heating required during the two years it has been in operation. Such performance is based in part on Hammond's care to first make the house heat-conserving. Since the house was in need of new siding and roofing at the time Hammond did the retrofit, it was relatively easy for him to include good insulation, weatherstripping, and insulated window shutters in the overall renovation. Then came construction of a needed room addition, which contains the solar heating system.

The large (575 square foot) room, with its concrete slab floor, was built onto the southern side of the house (see Figure 1-5). The south wall of the addition is virtually all windows. Hammond stacked 33 water-filled 55-gallon drums inside the room near the glass (see Figure 1-6). The drums, laid horizontally, are held together by special clips to form what has become known as a *drum wall* solar heating system, developed by Steve Baer in New Mexico. The drum wall, which will be discussed more extensively in Chapter 4, operates very simply. Sun shines through the windows and onto the black-painted exterior faces of the metal drums. Just as a stove heats the water in a metal teapot, the sun heats the drums and the water inside them. At night (or during cloudy periods), when the house begins to cool down, the heat in the water warms the room. Naturally moving air currents carry the heat throughout the house. Since the drum wall both collects and stores solar energy, there is no need for a separate storage tank. Heat is transferred into and out of storage directly, without the use of pumps, fans, or other machinery. This is the basic characteristic of what are called *passive* solar heating systems. In contrast, Heinemann's system (the previous example) relies on pumps to circulate water between the collectors and storage and from storage to the house. Systems of that sort are called *active*.

Hammond captures additional solar heat for his house with two 4 foot by 8 foot skylights cut into the south-facing roof. Each skylight is equipped with insulated interior shutters. They can be closed over the skylights by means of rope and pulley systems to keep heat in during winter nights or out during summer days. The face of the shutters and the area around the skylights are covered with aluminum foil to reflect additional sunlight into the rooms below. Extra heat storage is provided by a row of water-filled, 15 inch diameter drain culverts lined up in the bathroom.

Hammond's system has an added benefit—it cools the house during the summer. The drums and culverts are shaded from the sun during the day and soak up heat from the air in the house. At night, they are cooled by opening the windows and letting cool night air blow over them. They are then ready for another hot day.

The cost of this solar retrofit is difficult to separate from the cost of the complete house renovation, which totalled about $10,000. However, a major portion of the solar heating system was free, since with a little creative scrounging Hammond was able to get the barrels for his drum wall for nothing.

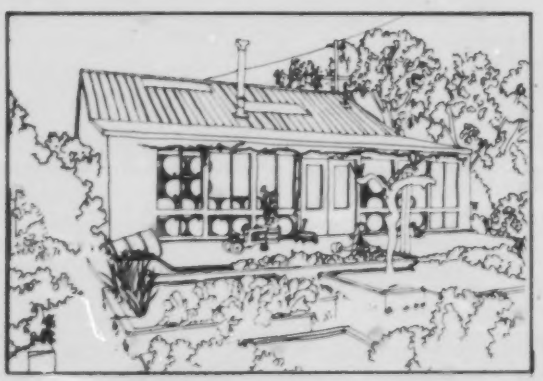

Figure 1-5: The Hammond house. Note the skylights and the drums in the south-facing windows.

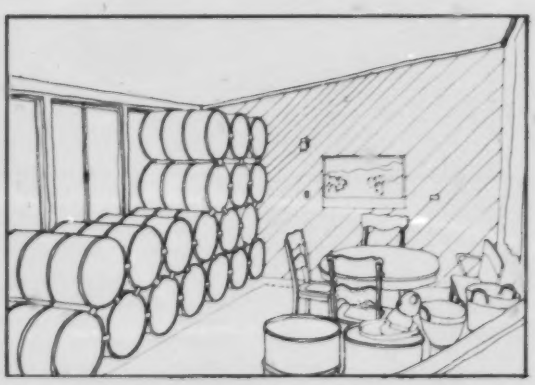

Figure 1-6: The Hammond drum wall from the inside. The ends of the drums facing the room are painted yellow; the outside ends are black for best absorption of solar energy.

These examples of Bay Area solar retrofits give you a good idea of what's possible with existing solar technology. Your first impression may well be that the technology isn't all that difficult—and you're right. Before continuing with a discussion of actual systems, however, let's look at some fundamentals of heat and solar energy.

Energy and heat

Energy, which is usually defined as "the ability to do work," has many different forms. One of the most familiar forms of energy is heat. Other forms are electricity, the chemical energy in natural gas, and the radiant (or light) energy of sunshine.

These different forms of energy can be converted from one into another, either by man-made devices that are designed for the job or by natural processes. For example, the energy in sunlight striking a rock is converted into heat energy, and the rock warms up. The chemical energy of natural gas is converted to heat when the gas is burned in a stove.

Heat energy is measured in BTUs (British Thermal Units). Since all forms of energy can be converted into heat, BTUs can also be used to measure the heating potential of natural gas, electricity, or sunshine. As shown in Figure 1-7, one BTU is the amount of energy required to raise the temperature of one pound of water (about a pint) by one degree Fahrenheit (1°F). Since this is a rather small amount—about equal to the heat from burning one kitchen match—it is more convenient to measure heat in *therms*. A therm is equal to 100,000 BTUs. We will use the therm as the basic unit of heat energy in this book.

Utility companies measure natural gas use in therms. Pacific Gas and Electric Company (PGandE), the major utility in the Bay Area, currently charges about 21¢ per therm for natural gas. Most houses in the Bay Area use natural gas for space and water heating. The average gas-using Bay Area household consumes about 1,000 therms per year for space heating and 350 therms per year for water heating.

Electricity use is measured in kilowatt-hours (KWHs), as explained in Figure 1-8. Your electric meter counts the KWHs used in your house and your utility company bills you for them. PGandE, for example, charges about 4¢ per KWH.

For purposes of comparison, there are about 29 KWHs in a therm. A little quick arithmetic shows that a therm of electricity costs about $1.16. Compared to 21¢ per therm for natural gas, electricity isn't a bargain. However, the days of natural gas as a cheap energy source are drawing to a close. Natural gas prices are rising rapidly, and it is predicted that by the mid-1980s they will be at least three times higher than they are now.

There's one more important point about energy. Energy makes things get hot, but temperature and heat are *not* the same. Temperature is a measure of the amount of molecular motion in a material. The greater the motion, the higher the material's *temperature*. The amount of *heat* in a material, on the other hand, depends both on its temperature and on how much of the material there is. For instance, it takes a lot more energy to heat a swimming pool one degree than it does to heat a gallon of water to the boiling point, even though the gallon ends up at a much higher temperature. So you cannot evaluate the performance of a solar system solely by the temperature to which it heats air or water—you also have to know how much air or water is being heated.

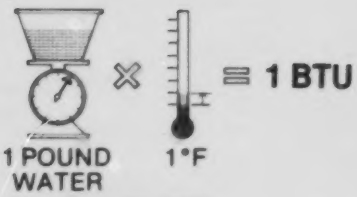

Figure 1-7: The BTU.

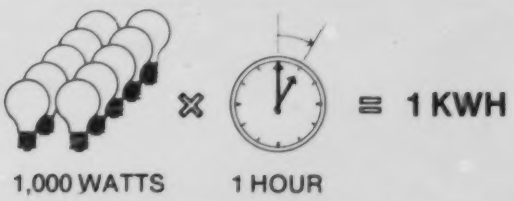

Figure 1-8: The KWH. Ten 100 watt bulbs burning for one hour use 1000 watt-hours or one KWH.

Putting sunshine to work

Now let's look at how much heat energy we can get from the sun. In round numbers, each square foot of ground in the Bay Area receives a yearly average of about 1,300 BTUs per day. Multiply 1,300 times the 365 days in a year and you get about 475,000 BTUs (4.75 therms) per year per square foot.

Remember that the average consumption of natural gas in a Bay Area house is about 1,350 therms per year for space and water heating. This means that if you could collect and use all the sunshine falling on a piece of ground about 15 feet by 20 feet (300 square feet), all your heating energy needs would be met! That 300 square foot area is probably smaller than the area of your yard or roof. The amount of solar energy available, then, is well matched to your needs. On this basis, the use of solar energy looks pretty promising.

Many types of systems have been devised to collect solar energy and put it to work heating your house, household water, or pool. They usually rely on a black, heat-absorbing surface that faces the sun and catches or *collects* the sunshine. In the rest of the book, we'll refer to this surface as the *collection area*. Sunshine heats the collection area, which in turn heats air or water that carries the heat to where it is used.

Energy is collected only when the sun is shining, but people need heat and hot water at night and on cloudy days as well. Excess heat collected during sunny hours is transferred to *storage* for later use. The practical limit on the amount of heat that can be stored is about 2 to 3 days worth of space heating. Since some Bay Area storms or cloudy periods last longer than that, most solar heating systems include a *back-up* heater that runs on conventional fuel. When the stored solar heat runs out, the back-up takes over. In a retrofit solar energy system, the back-up is usually the house's existing furnace or water heater.

Some systems, like the Farallones and Heinemann examples, require *circulation* of water (or air) between the collector and storage. *Delivery* of heat from the system to the house, water heater, or pool is required in all cases. Finally, *controls* are usually necessary to regulate the flow of heat. Controls can be thermostats, valves, dampers, or shutters, and can be either hand-operated or automatic.

The above functions are combined in some types of systems. In a drum wall, for instance, the drums serve as collection area, storage, and delivery, and controls are not necessary.

Sun angles, slope, and orientation

In the Bay Area, and everywhere else north of the Tropic of Cancer (23°N latitude), the sun makes a daily arc across the southern sky from east to west, as shown in Figure 1-9. In the summer, it passes nearly overhead—at noon on June 21, the sun is 75° up from the southern horizon. During the winter, it is much lower. On December 21, it is at its lowest, only 29° above the horizon at noon.

Good performance of a solar energy system depends on getting the maximum amount of sunshine onto the collection area. The *angle* at which the sun's rays strike the collection area effects how much energy they can deliver to each square foot. Their intensity is greatest when they are perpendicular to the surface they're striking, as shown in Figure 1-10. So the collection area should be aimed toward the south and tilted up to make its surface more at

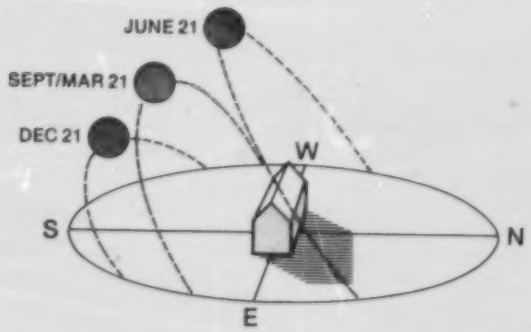

Figure 1-9: The sun's path across the sky at various times of the year.

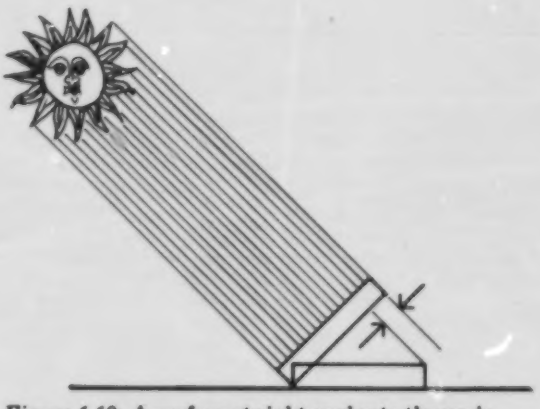

Figure 1-10: A surface at right angles to the sun's rays catches the most sunshine. Here, the surface lying on the ground does not receive the portion of the beam shown by the arrows. Tilted up to directly face the sun, the same surface receives the entire beam.

right angles to the sun's rays. As shown in Figure 1-11, *orientation* and *slope* are the two angles that describe how the collection area is aimed and tilted.

Since the angle that the sun's rays make with a fixed collection area is continually changing, it is necessary to pick a compromise orientation and slope for best overall performance. We recommend the following:

- The best orientation is due south (0°) or slightly toward the west, perpendicular to the strong, midday sun.
- The best slope for space heating in the Bay Area is about 48°, more or less perpendicular to the midday sun during the heating season. For water heating, a year-round compromise slope of about 38° is best. (See Figure 1-12.)
- The collection area must be unshaded during the critical hours between 9 a.m. and 3 p.m. The intensity of the sun's rays on the collection area is highest during these hours, so that is when most of the heat is collected.

You can vary from the best orientation or slope by 10° one way or the other with little effect on the amount of energy collected. Even large deviations may mean only 15% to 25% reductions, as shown in Figure 1-13. This means that buildings without "perfect," places for a collection area still can have good retrofit potential. Any generally south-facing surface, including vertical walls and low pitched roofs, is a potential collection area location. We'll discuss this in detail in Chapters 3 and 4.

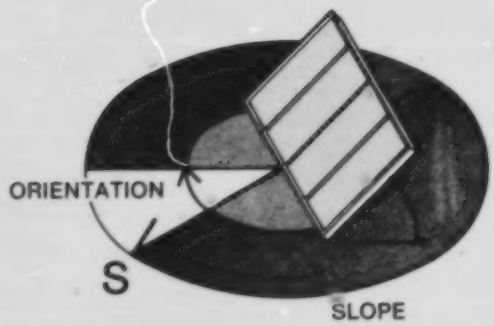

Figure 1-11: The *slope* of a surface is the angle up from the ground. The *orientation* is the rotation away from due south.

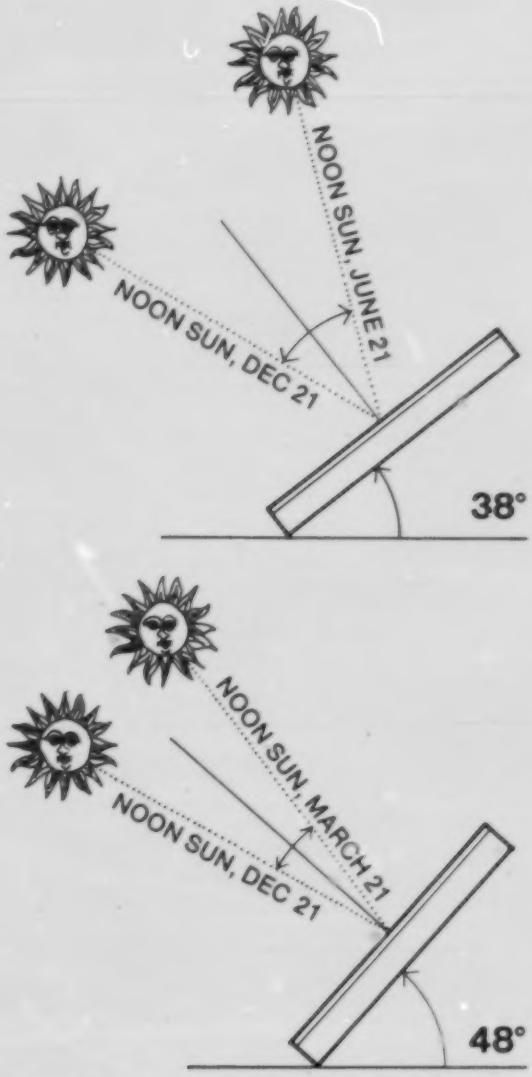

Figure 1-12: Ideal slopes. A slope of 38° is the best fixed slope for full-year water heating. For winter-only space heating, 48° is best. These angles result in the collection area being most nearly perpendicular to the sun's rays over the period when heat is required.

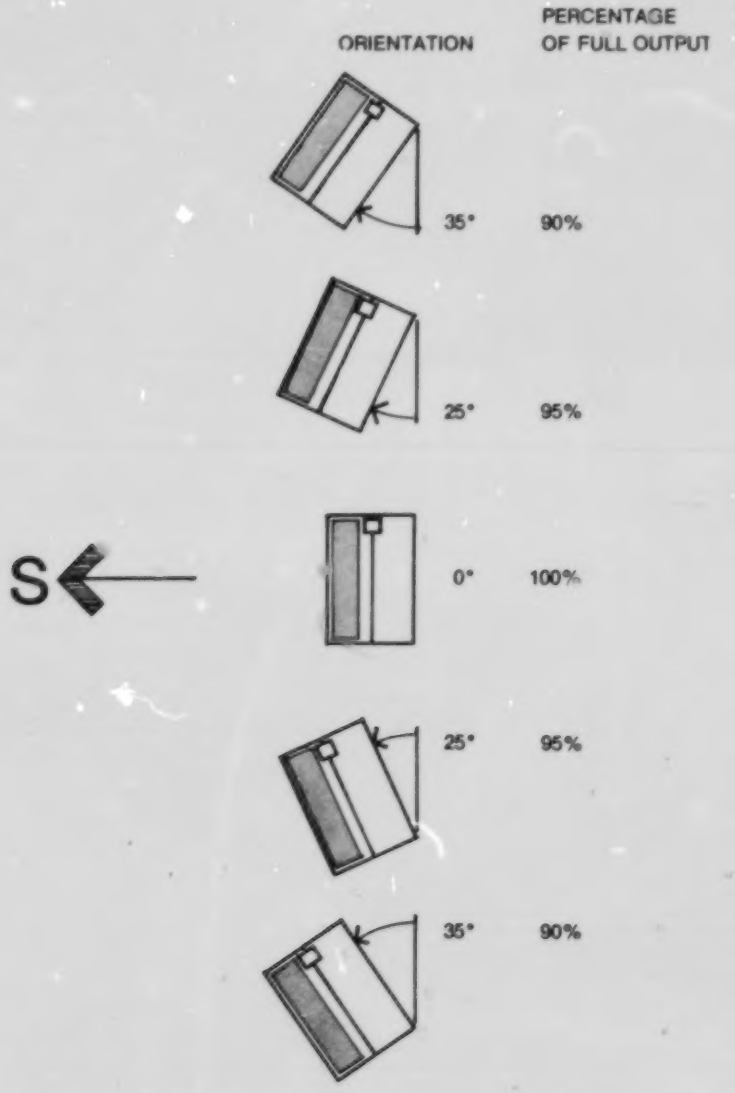

Figure 1-13: **Reduced performance of solar heating systems with non-ideal slopes and orientations. Since these reductions are not large, many non-ideal locations are practical for installing collection area.**

Windows as solar collectors

Given the solar gain available on a vertical surface, the simplest and most obvious means of solar heating is just to let the sun shine in through large, south-facing windows. In fact, in a house with any south-facing windows, that's what's already happening to some degree. The cat lying in the patch of sunlight on the floor, the "sunny" rooms of the house getting toasty in the afternoons – these are examples where windows are working as solar collectors.

But the sunshine through the windows seldom heats the whole house. There are two reasons for this. First, most houses don't have enough south-facing glass. Second, houses lack enough storage to soak up the heat and keep it until night. Even rooms that overheat during the day cool off all too rapidly in the evening.

On many buildings it's possible to add south-facing windows or skylights to increase direct solar heating. However, the extra window area can cause a "fry or freeze" situation unless storage is added as well. There must also be provisions for getting heat from the rooms receiving sunlight to the rest of the house. Providing such storage and delivery of solar heat gained through windows is the basis of passive solar heating systems.

Passive systems

Jon Hammond's drum wall is one example of a passive system – solar heat admitted by south-facing windows is stored in the water-filled barrels. As Figure 1-14 shows, the type of storage used and where it's located with respect to the windows varies for different passive systems. Tall metal tubes can be used to hold water instead of drums. Entire walls of solid concrete or grout-filled masonry store solar heat well. Slab floors can absorb solar heat coming in through windows, skylights, or greenhouse glass. Each of these passive systems will be discussed in more detail in Chapter 4. In each of these systems, the sunlight coming in through the glass must shine directly on the storage. If it doesn't, the storage can't absorb enough solar heat to provide much warmth for the house.

Most passive systems deliver heat to the rest of the house "naturally" – that is, the heat moves by itself without use of pumps or fans. There is some natural regulation of how fast heat moves from the storage into the house – the colder the house gets, the faster the heat is drawn out of the storage. That's how the drum wall works. In other passive systems, solar

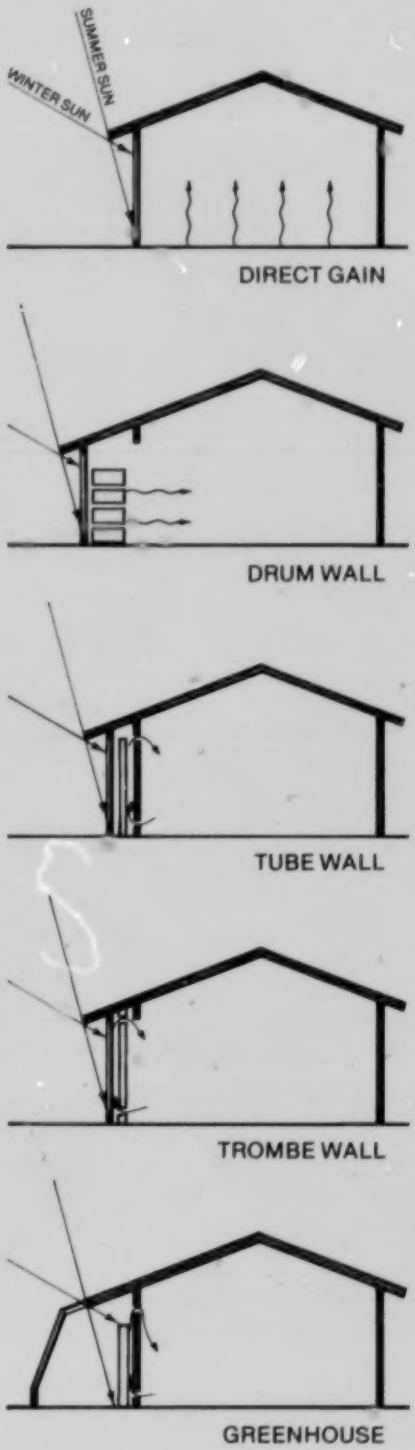

Figure 1-14: Passive systems. Although the specific arrangements vary, all of these systems rely on direct solar heating of storage. The storage then heats the house.

heat is "trapped" between the glass and storage (in the air space between the glass and a concrete wall, or in an entire greenhouse), and the amount of heat allowed into the house is controlled by opening and closing vents, either manually or automatically.

The performance of passive systems depends not just on how much solar heat they can collect, but also on how much of that heat is lost back out the glass at night. The most common solution to the problem of heat loss is to install movable insulation (such as insulating curtains) between the glass and the storage. The curtains or other devices are moved during the day to let the sunshine in, and closed at night to reduce heat loss.

Certain conditions must be present for you to do a simple passive retrofit. Since the basis for passive heating is to "let the sun shine in," your building must have extensive south-facing windows or skylights or places where they can be added. In addition, there must be a place close to the windows where storage can be located. The storage must receive midday sun. The problem here is that drums of water and masonry walls are so heavy that most existing floors can't support them. Get your floor checked by a structural engineer to be sure it can take the weight.

If your floor is not strong enough, there are at least two possible alternatives. One is to put the water or masonry wall on its own foundation on the exterior of the south wall. Another is the Hammond technique of turning a room addition into a solar heater that provides warmth for the rest of the house as well. We'll discuss these in Chapter 4.

We've presented the passive system approach to solar heating first because it is generally the simplest, the cheapest, and, if you like, the most "natural." As discussed above, however, there are situations which make it impossible to retrofit a building with a passive system. It also just may not be the approach that suits your style. If that is the case, consider an *active* system, like the Heinemann design. These systems are based on the use of *flat-plate collectors.*

The flat-plate collector

Flat-plate collectors are the most widely used active collectors for the water and space heating jobs we are considering. They are available from an ever-increasing number of manufacturers and can be readily constructed by the skilled do-it-yourselfer.

Flat-plate collectors absorb sunshine and heat either water or air. Their internal design varies accordingly. The heart of all flat-plate collectors, however, is the same: a black surface which gets hot when exposed to sunlight. This surface is called the *plate* or the *absorber.* Collectors used for home or water heating use metal absorbers, usually made of copper, aluminum, or steel. Plastic or rubber is used to make low-temperature absorbers for pool-heating.

The absorber plate is painted a dull black so that nearly all of the sunshine that hits it is absorbed and turned into heat. (White, bright

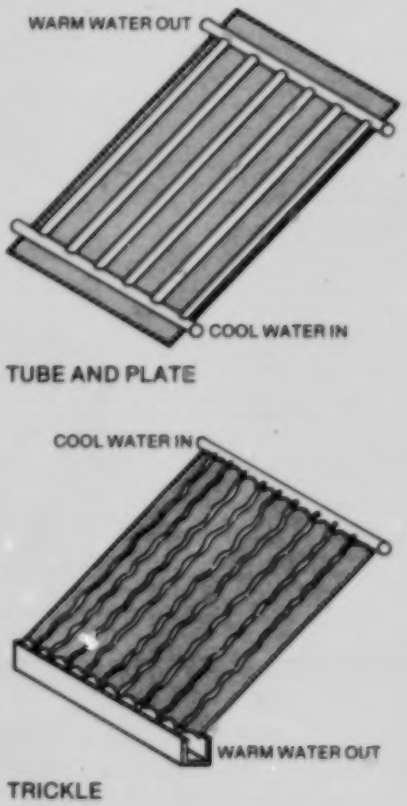

Figure 1-15: Two types of absorbers commonly used in water flat-plate collectors. In both cases, the sun heats the black absorber which in turn heats the water.

surfaces *reflect* sunlight.) To remove the heat for use, water or air is circulated in contact with the absorber. Figure 1-15 shows two of the possible arrangements for doing this with water. In a *tube and plate* water collector, heat flows from the hot plate into pipes or tubes, and then into the water circulating through the tubes. Another arrangement is used in the *trickle* collector – water runs down troughs in a corrugated plate and is caught by a gutter at the bottom. Air collectors channel the air directly past the plate, as shown in Figure 1-16.

The flow rate of the water or air through the collector affects its performance. Low flow rates allow the water or air to get very hot, but reduce the total energy collected due to large heat loses. Higher flow rates usually improve performance, but require larger pipes or ducts and more electricity for the pumps or fans. The optimum combination of performance and system cost usually occurs when about 1.2 to 2 gallons of water per square foot of collector circulates each hour. This results in a temperature rise through the collector of 10°F to 20°F on a sunny day. Air systems usually operate with a larger temperature rise because it is expensive to move large volumes of air. Typical flow rates are 2 to 4 cubic feet per minute per square foot of collector, with a resulting temperature rise through the collector of 40°F to 80°F.

Swimming pool collectors are usually run at high flow rates so the water is warmed only a few degrees on each pass. Since pool water is usually around 80°F, the absorber is often cooler than the air during the summer. This means there are no heat losses and a simple absorber plate makes an excellent pool heater.

On the other hand, a collector plate operating at 140°F can have large heat losses because of the lower surrounding temperature. For this reason, flat-plate collectors for home and water heating are designed with *glazing*. Glazing is a

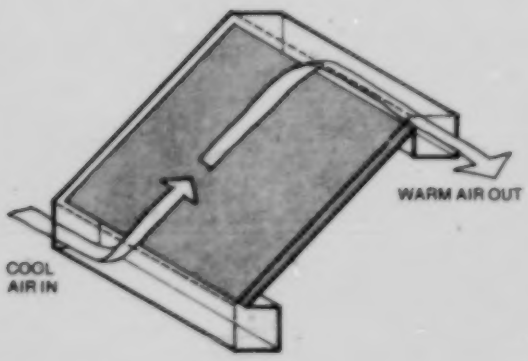

Figure 1-16: **An absorber for use in an air collector. The air is heated as it passes through the space behind the absorber surface.**

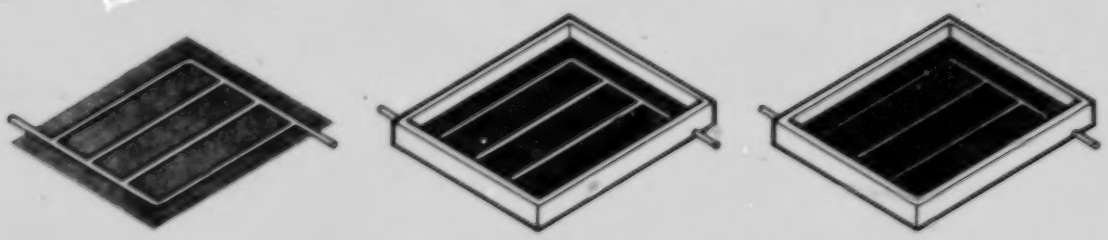

Figure 1-17: **The glazed flat-plate collector. The absorber plate is installed in an insulated, glazed box.**

cover of glass or other transparent material, such as rigid plastic, fiberglass, or plastic film. The glazing allows sunlight in to heat the plate, but reduces the amount of heat lost back to the surrounding air. To hold the cover glazing in place, a box is built around the collector. By insulating the bottom and sides of the box, heat loss from the absorber is further reduced.

The ideal box would have insulation over the top as well, but there is no available insulation that is transparent. Glazing provides some insulation, however, by trapping air in the space between it and the absorber. The more layers of glazing, the better the insulation, so in cold climates two or even three glazings are used to keep heat losses reasonably low. In the Bay Area, however, one glazing is generally sufficient because the climate is mild. Most of the systems discussed in Chapter 4 use single-glazed collectors.

Glazed collectors have a "sandwich-style" construction, as shown in Figure 1-17. The bottom layer is a wood or metal box that houses the rest of the collector. Next comes one to three inches of insulation. Then there is the absorber plate with pipes or ducts leading out through the box for circulation of water or air. The glazing material is the top layer and is installed with good caulking to keep out rain.

Flat-plate collectors on the market today are typically about the size of a door and 3-5 inches thick. As many collector panels as are needed can be connected together to make a larger collection area. Alternatively, collectors can be built on site, in which case they can be made to fit the available space. The result is often a more natural, custom look.

Active systems

Active systems using flat-plate collectors can be designed to heat water, houses or other buildings, or pools. Water collectors can be used for any of these jobs, while air collectors generally are used only for space heating. Both types are discussed in Chapter 4.

Active systems usually tie into an existing heating system or water heater (which are active systems themselves). This means they require less obtrusive alteration of the inside of your house than some of the passive systems. The exterior changes, on the other hand, may be more obvious, since flat-plate collectors are often roof-mounted and resemble large skylights on a pitched roof.

Most active systems include some sort of storage unit. In water systems, heat is stored simply by keeping solar heated water in a tank, as mentioned in the retrofit examples. The tanks for water heating systems are similar to regular water heaters, but with capacities of 60 to 120 gallons. Space heating systems, such as Heinemann's, use tanks ranging in size from 500 to 2000 gallons or more. These can be made of concrete, steel, or fiberglass. When heat is needed, hot water is withdrawn from the top of the tank, while cooler water from the city water mains or the heating system return line comes in at the bottom. The cool water is heated as sunshine conditions permit.

In an air system, a *rock bed* is generally used. A rock bed is made by building a box-shaped enclosure, measuring perhaps six feet wide by six feet high by ten feet long, and filling it with plum-sized rocks, as shown in Figure 1-18. Air ducts are installed so the solar-heated air passes through the rocks and warms them. The heat can be removed when needed by passing air from the house through the rock bed. The rocks transfer their heat to the air and are cooled in the process, readying them to be heated again. Rock beds are proving to be very satisfactory solar storage units; after all, there's not a whole lot that can wear out in a pile of rocks. Only the weight and size of rock beds may present problems.

Active systems always include circulation, which consists of pipes (for water systems) or ducts (for air systems) that are identical to the ones in standard plumbing and heating systems. They connect the collectors to the storage tank or rock bed. When the sun is shining, a pump or fan is turned on by the controls (unless a thermosiphon system is

used—see Figure 1-2) and circulates water or air from storage through the collector and back to storage, gradually warming it up. As heat is needed, it is withdrawn from storage (or directly from the collector) for delivery via the existing heating system.

Additional controls, usually automatic, turn on the back-up heater when heat is needed and the stored solar energy can't provide it. We will see how this works in specific cases in Chapter 4.

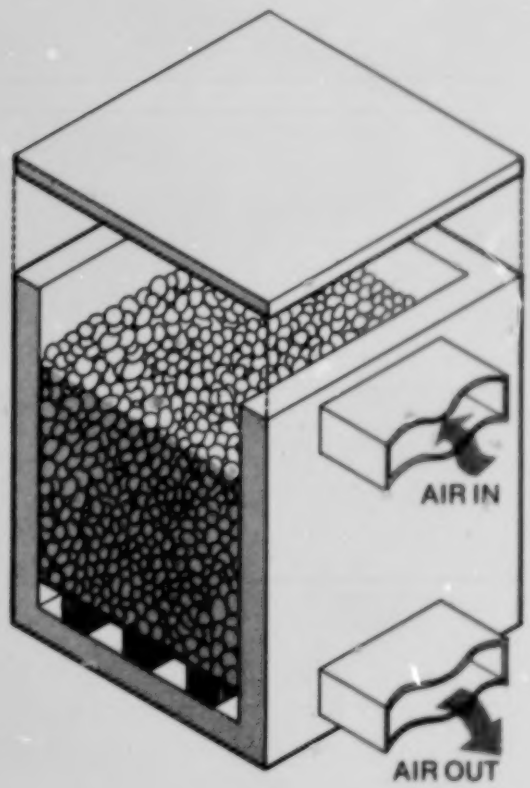

Figure 1-18: Cut-away view of a rock bed heat storage unit. Hot air is blown through the rocks and heats them. At a later time, cool air is blown through and the warm rocks heat it.

Freezing

Water collectors can be seriously damaged by freezing. Water expands as it freezes and will burst the pipes. While it freezes only occasionally in the Bay Area, collectors in this region *must* be protected from low temperatures because it takes only one freeze to destroy a collector. There are three methods of freeze protection:

- Heating the collectors, either with electric elements or by pumping warm water from the storage tank through the collectors.
- Draining the collectors, either every night or on cold nights.
- Adding antifreeze to the water in the system.

Any of these options makes a system more complicated, but there is no way to avoid this problem. Freeze protection must be automatic—a manually protected collector may freeze if you don't make it out of bed to drain it on a cold night.

Air collectors can't freeze, and this is a point in their favor. Passive collectors such as drum walls will not freeze because of the large quantity of water involved. The weather would have to remain sunless and well below freezing for several days to freeze that amount of water.

Leaks

Since many active solar systems circulate water from one part of your house to another, there's always the chance of damage from plumbing leaks. Using a good plumber will minimize this problem. It is also a wise idea to isolate any potentially leaky equipment to reduce the chance of water damage; for instance, install a sheet metal tray underneath a water heater storage tank. Air systems, of course, don't have this problem.

There is also the possibility of roof leaks. These can be caused by excessive walking around on a roof during installation of collectors. Wear soft shoes (such as sneakers) and walk gently to reduce the chance of leaks. You can also tack sheets of plywood down to the roof and walk on those. In addition, any pipes going through a roof must be installed in a manner similar to vent pipes. Without that type of flashing, leaks around the pipes are likely.

Corrosion

Collectors and Piping. Any pipe or water channel that carries tap water *must* be copper, galvanized steel, or plastic. Plastic is only acceptable for low-temperature use and as permitted by local plumbing codes. Aluminum and untreated steel will corrode very rapidly (within a few months) if exposed to tap water and cannot be used in that situation. By contrast, copper has been used for hot water piping for years and has proven its durability.

In recirculating systems, where the same water is used over and over again (as is common in heating systems), steel or aluminum can be used if chemicals called *corrosion inhibitors* are added to the water. You can't drink water containing corrosion inhibitors, so to provide hot water with a system of this type, a heat exchanger (often a coil of pipe) must be used, as is done in the Heinemann system. The heat exchanger transfers heat from the solar-heated water in the storage tank to your tap water. The water chemistry of systems using corrosion inhibitors must be checked and corrected every few months. Although this sort of testing is unusual for house-sized systems, it is commonly done on large commercial systems. Some people find the added maintenance is offset by the lower initial cost of steel or aluminum collectors.

Collector plates can corrode from the outside as well as from the inside. Outside corrosion occurs when different metals, such as steel and copper, come in contact with each other in the presence of water. Water occasionally condenses in collector boxes and often the nails or screws used for assembly are made of different metals than the absorber. Care must be taken to keep them from touching each other.

Some manufacturers are making absorbers that have copper pipes (for good corrosion resistance) attached to an aluminum or steel plate. While this is a direct violation of the above principle, experience with similar arrangements in air conditioning equipment indicates that this may prove to be a durable scheme. In the absence of long-term experience with this combination, be sure to get a good guarantee if you buy a plate of this sort.

Storage. Steel storage tanks that hold tap water must be lined with glass or cement to protect them from corrosion. Unlined steel tanks can be used in re-circulating systems, but the water chemistry of the system must be monitored, as described above. Concrete tanks are extremely durable, if built correctly. Fiberglass tanks hold promise of being inexpensive, but they may have difficulty withstanding high temperatures. Again, get a guarantee!

The completely closed storage units used in passive systems do not seem to present any corrosion problems. For safety, corrosion inhibitors should be added to the water in drum walls and tube walls. So far, though, none of these systems has corroded or rusted out.

Heat damage to collector insulation

Under relatively low-temperature conditions, such as around storage tanks, most insulation materials can be used. In flat-plate collectors, however, temperatures can be high enough to melt some foam insulations, such as styrofoam. Also, some foams give off corrosive fumes at high temperatures, which can damage the absorber plate. The safest all-around choice is ordinary fiberglass building insulation. If you are considering using a foam insulation, get reliable information on its temperature rating.

Glazing durability

The ideal glazing material is highly transparent, unbreakable, light-weight, durable, and a good insulator. In spite of some shortcomings, glass remains the overall best choice for a glazing material. Properly installed glass has an indefinite life – there are many 100-year-old buildings with their original windows. However, glass is fairly expensive, especially the less breakable tempered glass. Fiberglass costs about 1/3 as much as glass and is lighter and easier to work with. It also doesn't break easily. Fiberglass degrades at temperatures above 200°F, however, and therefore cannot be used as the inner glazing of a double-glazed collector. Fiberglass probably has a 10 to 20 year maximum lifetime. Plastic films usually are even cheaper than fiberglass, but have correspondingly shorter lifetimes – perhaps 5 to 7 years.

Performance Boosters

Reflectors

Both active and passive system performance can be improved with simple plywood and aluminum foil reflectors (white or aluminum paint can also be used) mounted so they bounce extra sunshine onto the collection area, as shown in Figure 1-19. Reflectors are an integral part of one of the systems discussed in Chapter 4, the breadbox water heater, and work particularly well with south wall systems, such as drum walls.

Selective surfaces

Some flat-plate collector manufacturers apply a *selective surface* to their absobers. A selective surface absorbs solar energy like black paint (and usually looks black as well), but loses heat at a lower rate than paint does and thus is more efficient at collecting solar energy. Selective surfaces are used on a number of collectors now on the market, but they add considerably to the cost and generally are relatively untested and less durable than paint. If you are considering buying such a collector, be cautious and get a long-term guarantee.

Figure 1-19: A reflector mounted in front of a vertical collection area increases the amount of sunshine received.

Other Solar Applications

There are several other types of solar applications that are not yet technically or economically feasible for the uses discussed in this book.

Concentrating collectors

Mirrors or lenses can be used to concentrate the sunshine that falls over a large area onto a smaller absorber. Concentrators achieve higher temperatures than flat-plate collectors and so can be used to provide hotter water (180° and up) and also for cooking or making steam. Some concentrators *track* the sun, pointing directly at it throughout the day. Tracking involves complicated and expensive mechanisms. Other types, called *fixed concentrators*, can be permanently mounted in one position. Some concentrators show promise for large high-temperature systems, but don't appear to be justified at this time for the simple heating applications we're discussing.

Photovoltaics or "solar cells"

These devices change sunshine directly into electricity. Although this ability makes solar cells very useful, they are so expensive that they are used only on satellites, ocean buoys, and other places where it's hard to run an extension cord. At current prices, it costs about $100,000 to buy enough solar cells for one house's energy needs. There is research underway to lower the cost, but a lot of progress will have to be made before they will be practical for houses.

Solar air conditioning

Although the phrase "solar heating and cooling" is often used in connection with solar energy, we have so far discussed only solar heating. The reason for this is that active solar air conditioning involves elaborate equipment and very expensive collectors that up to now have proved to be uneconomical and unreliable for use in small buildings. For that reason, we are not going to consider active cooling systems for houses.

However, rock beds and most passive systems can be used to cool as well as heat. Jon Hammond's drum wall is an example. In that system, the drums are cooled off at night and keep the house from overheating during the following day. In Chapter 4, we will point out the systems that can provide cooling.

The Thermal Payoff

We've seen in this chapter that many different types of systems can be used, each with its own set of advantages and disadvantages. We also saw that a square foot of ground receives about 4.75 therms of solar energy per year. How much of that energy can we actually capture and use with practical systems? This is the subject of much of the rest of this book.

The amount of energy collected depends on the type of system, how large it is, how it is used, and where it is located. With typical space heating systems in the Bay Area, you can expect to get 1/2 to 2 therms per year from each square foot of collection area. Solar water heaters have slightly higher outputs, with a range from 1/2 to 3 therms per year per square foot of collection area. These figures are quite promising. With the background that this chapter provides, you can now go on to determine what sort of system will do the most for you. The first step in this process is to calculate your current energy use and how much it can be reduced by conservation. Chapter 2 will show you how to do this.

2: Energy Estimating and Conservation

How much energy do you now use to heat your water, your house or building, or your pool? How much could you reduce your present consumption by conserving energy? You'll need the answers to these questions in Chapter 5, along with the results of and information in the next two chapters, to determine how large a collection area your solar energy system should have (to "size" it). If you decide not to use solar energy (or can't), this chapter will still be of value to you as you will learn how to substantially reduce your present fuel consumption and, therefore, your fuel bills.

If solar energy *is* for you, this chapter can save you a considerable amount on the initial cost of your system. In the first part of this chapter, you will estimate the demand you would make on a solar heating system if you continued your *present* consumption patterns. Ordinarily, this would be used to size your system. However, if you *reduce* your demand, as discussed later in the chapter, you also reduce the collection area required to provide a given percentage of it.

A smaller collection area means a lower initial cost. As we will discuss in Chapter 6, the economic feasibility of using solar energy depends, for most people, almost entirely on the initial cost of the system. Energy conservation provides a relatively inexpensive way to reduce that first cost, as it is generally much cheaper to *save* energy with simple conservation measures than to *provide* it with a solar heating system. For example, it costs nothing to lower your thermostat at night. This can easily reduce the amount of energy you use for space heating by 20%. To add 20% to the capacity of a solar heating system, on the other hand, could cost hundreds of additional dollars.

In most cases, it's possible to make a good estimate of your energy use based on your utility bills or personal records. It takes a bit of wrestling with them, however. First, you have to subtract the uses of energy that we're not concerned with here, such as cooking and clothes drying, from your total annual energy use. The remainder is then divided into the various potential uses of solar energy: water heating, space heating, and pool heating. These figures tell you your fuel use for each application. Some of the fuel used is actually wasted due to pilot lights and burner inefficiencies, so adjustments are made to the use figures to compensate for these losses. The result, in each case, is called the *Net Energy Use*. These are the actual amounts of heat you use for water, space, and pool heating.

Worksheets 1 - 6 have been provided to assist these calculations. Sample, completed worksheets have also been provided.

Although this chapter is generally aimed at the homeowner, the principles and procedures involved are applicable to both homes and businesses. Many small businesses have space heating or water heating systems similar in design and operation to those of households, even though the amounts of energy used may be larger. So most business owners can calculate their energy use with the methods that follow.

Part I: Estimating Your Energy Use

If you have been keeping records of your energy consumption or your utility bills, get them out now. If you don't have records or haven't saved your bills, you can obtain a record of your old bills by calling the local office of your energy utility. Pacific Gas and Electric Company (PGandE), for example, will send you a record of your account for the preceding year or more. A sample is shown in Figure 2-1. If for some reason your last year's bills won't work (perhaps you've moved recently or changed your heating system), there are several ways of estimating your energy use, as discussed beginning on page 31.

It is important that you use data for as many years as possible. Any single winter may be significantly different from an "average" winter. If the energy consumption you use to size your solar heating system was from a year with an exceptionally mild winter, for example, you will both undersize the system and underestimate the fuel savings it will produce. There is no practical way for you to adjust for atypical weather except by averaging records over several years.

The number of therms of natural gas, kilowatt-hours of electricity, or gallons of propane or fuel oil shown on your records or bills tells you how much energy you have been using in the past on a month-by-month basis. Use these figures to prepare an Energy Record (Worksheet 1). Note that the *cost* of your energy is not important for this purpose; we are concerned with the *amount* of energy used. If you foresee changes in the years ahead, such as fewer people in the home or the addition of a clothes dryer, you should adjust the figures on the Energy Record to account for the anticipated changes. Use the information in the rest of this chapter to make the best estimate you can of what your future energy use will be.

R403CS PACIFIC GAS AND ELECTRIC COMPANY
NAME STATEMENT OF ACCOUNT 07/27/76 REQUESTED BY
ACCOUNT BILLING TRANSACTIONS

CURRENT GAS * * * * * SCHEDULE G2 CURRENT ELECTRIC * * * * * SCHEDULE D1 BILLING DEMAND LOAD .0

DATE	THERMS	CHARGE	DATE	KWH	CHARGE	CITY TAX	TOTAL CHARGES
07/21/76	62	9.92	07/21/76	70	3.30	.73	13.95

STATE SURCHARGE INCLUDED IN ELECTRIC CHARGE

PRIOR GAS * * * * * PRIOR ELECTRIC * * * * *

06/21/76	78	12.48	06/21/76	71	3.34	.87	16.69
05/20/76	180	28.80	05/20/76	84	3.69	1.79	34.28
			04/20/76	127	4.81	.26	5.07
03/22/76	168	26.88	03/22/76	126	4.78	1.74	33.40
02/20/76	220	35.20	02/20/76	172	5.98	2.26	43.44
01/21/76	262	41.92	01/21/76	194	6.55	2.67	51.14
12/19/75	239	36.64	12/19/75	176	6.09	2.35	45.08
11/19/75	160	23.36	11/19/75	141	5.17	1.57	30.10
10/20/75	70	11.20	10/20/75	84	3.70	.82	15.72
09/19/75	48	7.68	09/19/75	80	3.91	.64	12.23
08/20/75	25	4.00	08/20/75	70	3.55	.42	7.97
07/22/75	56	8.96	07/22/75	81	3.95	.71	13.62
06/20/75	72	11.52	06/20/75	70	3.55	.83	15.90
05/21/75	90	14.40	05/21/75	85	3.75	1.00	19.15

PRIOR ELECTRIC BILLING DEMAND LOAD

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	0	0	0	0	0	0	0	0	0	0	0

Figure 2-1: A sample customer record from PGandE.

Sample Worksheet 1

Worksheet 1:

Energy Record

	Natural Gas	Electricity	Propane	Fuel Oil
1. January	262 therms	_____ KWH	_____ gal.	_____ gal.
2. February	220	_____	_____	_____
3. March	168	_____	_____	_____
4. April	90	_____	_____	_____
5. May	90	_____	_____	_____
6. June	75	_____	_____	_____
7. July	56	_____	_____	_____
8. August	52	_____	_____	_____
9. September	48	_____	_____	_____
10. October	70	_____	_____	_____
11. November	160	_____	_____	_____
12. December	239	_____	_____	_____
13. Total	1530 therms	_____ KWH	_____ gal.	_____ gal.
14. Conversion factor	× 1.0	× .034	× .92	× 1.4
15. Total Annual Energy Use	1530 therms	_____ therms	_____ therms	_____ therms

How to prepare your Energy Record

You need to fill out only those columns on Worksheet 1 that are for the fuels you use for water, space, and pool heating. For instance, if you have a gas furnace and water heater, fill out only the "Natural Gas" column. Sample Worksheet 1 shows this case. If you have a gas furnace and an electric water heater, fill out both the "Natural Gas" and "Electricity" columns. Here's how to fill out Worksheet 1:

- Lines 1-12: *Enter the* average *amount of fuel used in each month.* If you have records for the same month in more than one year, add them together and divide by the number of years. For example, in the sample customer record shown in Figure 2-1, the number of therms for June 1975 is 72 and for June 1976 is 78. 72 + 78 = 150 ÷ 2 = 75, the entry for June in Sample Worksheet 1. There are some points to keep in mind when figuring average uses.

  1. It is quite common for utilities to occasionally skip one or two monthly meter readings. The next month's bill covers all the months since the last bill. To get an estimate of energy use during each month, divide the total amount by the number of months covered. For example, April 1976 has no entry in Figure 2-1, so the May amount of 180 therms was divided by 2, and 90 was entered for both April and May on Sample Worksheet 1.

  2. Watch out for atypically low or high energy uses in one month. You might have been on vacation or had five house guests all month, for example. If you have a low or high reading, replace it with the average of the amounts for the months before and after. For example, the Figure 2-1 entry for August 1976 is very low. In Sample Worksheet 1, 52 was used, the average of July (56) and September (48).

  3. Don't worry if your record or bills list the energy used from mid-month to mid-month. When filling out your Energy Record, make your entry in whichever month contains the majority of the days covered by your utility bill. For example, if your record goes from 10/20/75 to 11/19/75, enter the number of therms used during that period as the November energy use in you Energy Record; if it goes from 10/10/75 to 11/9/75, enter it as October.

- Line 13: *Add your monthly amounts to get the annual total.*
- Lines 14-15: *Convert each annual total to therms by multiplying it by the conversation factor shown on Line 14. The result is your* Total Annual Energy Use *for that fuel. Round off the result to the nearest whole therm (not just here, but throughout the book) and enter it on Line 15.*

Figuring your energy use breakdown

Now begins the task of figuring out how many therms of your *Total Annual Energy Use* go for space heating, water heating, or pool heating. You have to read only the sections that apply to your situation, so first look at the Checklist on the next page.

As you can see, the Checklist has been divided into different categories. *Read each category in the Checklist carefully.* Then go back and put a check in the box by each category that fits your situation. You may end up with only one check; you may have two or three. The number doesn't matter so long as your water, space, and pool heating situations are covered.

Under each category you checked, you will find the number(s) of the worksheet(s) or page(s) that will guide you in calculating your energy consumption for a particular fuel and use. Turn to the sample completed worksheet(s). Fill out your own worksheet(s) using the samples for guidance and enter the results on Worksheet 6.

When you've finished, go on to the second part of the chapter, beginning on page 32, and find out how to conserve energy in each case.

The Checklist

Read the entire Checklist, then go back and check off the categories that apply to your particular home or business. Turn to the worksheet(s) or page(s) indicated and make your own estimate.

☐ **You use natural gas for space heating, but not for water heating**

and

you do *not* use space heating during the summer.

- ***Use Worksheet 2 (see page 26 for the sample completed Worksheet 2).***

☐ **You use natural gas for both space heating and water heating**

and

you do *not* use space heating during the summer.

- ***Use Worksheet 2 (see page 26 for the sample completed Worksheet 2).***
- ***then use Worksheet 3 (see page 27 for the sample completed Worksheet 3).***

☐ **You use natural gas for space heating, but not for water heating**

and

you use space heating all year.

- ***Use Worksheet 4 (see page 28 for the sample completed Worksheet 4).***

☐ **You use natural gas for both space heating and water heating**

and

you use space heating all year.

- ***Use Worksheet 5 (see page 29 for the sample completed Worksheet 5).***

☐ **You use electricity for water heating.**

- ***See page 30.***

☐ **You use electricity for space heating.**

- ***See page 30.***

☐ **You use propane or fuel oil for space or water heating.**

- ***See page 30.***

☐ **You have no records or utility bills.**

- ***See page 31.***

☐ **You use natural gas for pool heating.**

- ***See page 31. Important: If you checked this category, read this section* before *you fill out the worksheet(s) for space and water heating.***

Worksheet 2:

Energy Use for Space Heating with Natural Gas
No Summer Space Heating

1. *Enter your natural gas* Total Annual Energy Use *from Line 15 of your Energy Record (Worksheet 1).* 1530 (1)

2. a. *Enter the number of therms you used during each month you did* not *use your furnace.*

   May _____

   June _____

   July 56

   Aug 52

   Sept 48

   Oct _____

   Total 156 (2a)

   b. *Divide the total by the* number *of months you did* not *use your furnace to get your average monthly energy use for the months you did no space heating.*

   156 (2a) ÷ 3 (Number of months) = 52 (2b)

   c. *Multiply Line 2b by 12.*

   52 (2b) × 12 = 624 (2c)

3. *Subtract Line 2c from Line 1.* 906 (3)

4. Burner efficiency correction: Only 70% of the heat from the gas actually warms your house (the rest goes up the flue). *Multiply Line 3 by .7 to get your* Net Energy Use for Space Heating.

   906 (3) × .7 = 634 (4)

Transfer Line 4 to Worksheet 6, Line 5.

Sample Worksheet 3

Worksheet 3:

Energy Use for Water Heating with Natural Gas
No Summer Space Heating

Worksheet 2 must be completed first.

1. *Enter result from Line 2c of Worksheet 2.* 624 (1)

2. Adjustments for other uses of gas:

   a. Cooking:

   Enter 100 for gas stove with pilot lights
   60 for gas stove without pilot lights
   0 for non-gas stove 100 (2a)

   b. Clothes drying:

   If you have a gas dryer, calculate your energy use as follows: 20 × 4 (Number of people in household) = 80 (2b)

   c. Other uses:

   Estimate your gas consumption for other uses such as barbecues or outdoor lighting. Your utility can help you with this. Enter the total therms per year. 0 (2c)

   d. *Add Lines 2a, 2b, and 2c.* 180 (2d)

3. *Subtract Line 2d from Line 1.* 444 (3)

4. Furnace pilot light correction. Your furnace pilot light consumes about 7 therms each month that it burns. *Enter the number of months per year your pilot light is on (some people turn it off during the summer) and multiply by 7.* 12 (Number of months) × 7 = 84 (4)

5. *Subtract Line 4 from Line 3.* 360 (5)

6. Standby loss correction: Your water heater wastes about 120 therms per year due to tank heat losses. *Subtract 120 from Line 5.* 360 (5) − 120 = 240 (6)

7. Burner inefficiency correction: Only 70% of the heat from the burning gas actually warms your water. *Multiply Line 6 by .7 to get your* Net Energy Use for Water Heating. 240 (6) × .7 = 168 (7)

Transfer Line 7 to Worksheet 6, Line 1.

Sample Worksheet 4

Worksheet 4:

Energy Use for Space Heating with Natural Gas Space Heating All Year

1. *Enter your natural gas* Total Annual Energy Use *from Line 15 of your Energy Record (Worksheet 1).* — 1170 (1)

2. Adjustments for other uses of gas:

   a. Cooking:

   Enter 100 for gas stove with pilot lights
   60 for gas stove without pilot lights
   0 for non-gas stove — 100 (2a)

   b. Clothes drying:

   If you have a gas dryer, calculate your energy use as follows: — 20 × 4 (Number of people in household) = 80 (2b)

   c. Other uses:

   Estimate your gas consumption for other uses such as barbeques or outdoor lighting. Your utility can help you with this. Enter the total therms per year. — 0 (2c)

   d. *Add Lines 2a, 2b, and 2c.* — 180 (2d)

3. *Subtract Line 2d from Line 1.* — 990 (3)

4. Furnace pilot light correction. Your furnace pilot light consumes about 7 therms each month that it burns. *Enter the number of months per year your pilot light is on (some people turn it off during the summer) and multiply by 7.* — 12 (Number of months) × 7 = 84 (4)

5. *Subtract Line 4 from Line 3.* — 906 (5)

6. Burner efficiency correction: Only 70% of the heat from the gas actually warms your house (the rest goes up the flue). *Multiply Line 5 by .7 to get your* Net Energy Use for Space Heating. — 906 (5) × .7 = 634 (6)

Transfer Line 6 to Worksheet 6, Line 5.

Note: This sample does not correspond to the case shown on Sample Worksheet 1.

Sample Worksheet 5

Worksheet 5:

Energy Use for Space and Water Heating with Natural Gas Space Heating All Year

1. *Enter your natural gas* Total Annual Energy Use *from Line 15 of your Energy Record (Worksheet 1).* — 1530 (1)

2. Adjustments for other uses of gas:

   a. Cooking:
   Enter 100 for gas stove with pilot lights
   60 for gas stove without pilot lights
   0 for non-gas stove — 100 (2a)

   b. Clothes drying:
   If you have a gas dryer, calculate your energy use as follows:
   20 × 4 (Number of people in household) = 80 (2b)

   c. Other Uses:
   Estimate your gas consumption for other uses such as barbecues or outdoor lighting. Your utility can help you with this. Enter the total therms per year. — 0 (2c)

   d. *Add Lines 2a, 2b, and 2c.* — 180 (2d)

3. *Subtract Line 2d from Line 1.* — 1350 (3)

4. *Enter your estimated Natural Gas Use for Water Heating from Column B of Table 2-1 (page 30).* — 360 (4)

5. *Subtract Line 4 from Line 3* — 990 (5)

6. Furnace pilot light correction. Your furnace pilot light consumes about 7 therms each month that it burns. *Enter the number of months per year your pilot light is on (some people turn it off during the summer) and multiply by 7.*
   12 (Number of months) × 7 = 84 (6)

7. *Subtract Line 6 from Line 5.* — 906 (7)

8. Burner efficiency correction: Only 70% of the heat from the gas actually warms your house (the rest goes up the flue). *Multiply Line 7 by .7 to get your* Net Energy Use for Space Heating.
   906 (7) × .7 = 634 (8)

9. *Enter your estimated* Net Energy Use for Water Heating *from Column A of Table 2-1 (page 30).* — 168 (9)

Transfer Lines 8 and 9 to Worksheet 6, Lines 5 and 1.

Electric water heating

If you have an electric water heater, its energy use probably is buried in with so many other things (lights, refrigerators, etc.) that it's impossible to dig it out. Your best bet is to use Table 2-1. Find the *Net Energy Use* in Column A corresponding to the number of people in your household. *Enter this amount on Line 1 of Worksheet 6.* (Sample Worksheet 6 is on page 34.)

Electric space heating

The energy consumption of an electric space heating system often is difficult to estimate. If you don't have air conditioning *and* don't use any space heating during the summer, you can use a procedure based on that used in Worksheet 2. Where the worksheet calls for therms on Line 2a, be sure to convert your KWH figures into therms by multiplying them by .034. Also, electric furnaces are nearly 100% efficient, so skip Line 4. Use the amount on Line 3 as the *Net Energy Use* value. *Enter it on Line 5 of Worksheet 6.* (Sample Worksheet 6 is on page 34.)

If you can't use this procedure (perhaps you use air conditioning during your non-heating months), you will have to calculate your space heating needs directly. This is done by determining the amount of heat lost from your building (assuming a particular inside temperature) during the heating season. *The California Energy Design Manual* (Chapter 8, reference A-9) explains how to do this. You can also get help from an architect, engineer, or solar consultant. *Once you have calculated your building's heat loss, you can calculate and enter your* Net Energy Use for Space Heating *on Line 5 of Worksheet 6.*

Propane or fuel oil for space or water heating

The conversion factors provided on Line 14 of Worksheet 1 enable you to determine the equivalent number of therms for your consumption of propane or fuel oil. Once you have made the conversion, you can proceed as if you used natural gas. Go back to the Checklist, and substitute "propane" or "fuel oil" for "natural gas." Find the use(s) of natural gas that correspond to your use(s) of propane or fuel oil, and use the specified worksheet(s). In some cases, you will have to convert monthly use values to therms in order to complete the worksheets. Also, substitute "propane" or "fuel oil" for "natural gas" or "gas" when using the worksheets so there is less chance of confusion about which adjustments are appropriate. Finally, fuel oil furnaces don't have pilot lights, and the standby losses for a fuel oil water heater are only about 50 therms per year.

Table 2-1

Typical Annual Water Heating Energy and Fuel Use (therms per year)

Number of people in household	Column A: Net Energy Use	Column B: Natural Gas Use	Column C: Electricity Use
1	42	160	72
2	84	220	114
3	126	300	156
4	168	360	198
5	206	410	236
6	244	462	274
7	282	515	312
8	320	568	350

When you have no records or utility bills

You may not be able to obtain copies of your old utility bills. Or maybe your situation has changed recently in ways that will significantly affect your future fuel bills—perhaps you've just moved, added a swimming pool, or installed a new central heating system. In cases such as these, you can't use the worksheets, so your estimates probably will be less accurate than the results the worksheets provide.

- *Water heating:* Find the figure that applies to your case in Column A of Table 2-1. *Enter it on Line 1 of Worksheet 6.* (Sample Worksheet 6 is on page 34.)
- *Space heating:* Your best bet is to calculate your building's heat loss, as discussed under "Electric Space Heating" on page 30. You could also make a crude estimate of your space heating energy use based on the average annual natural gas consumption figures for the PGandE service area, as follows:

Heating system	Net Energy Use
Electric	345 therms
Natural gas, propane, or fuel oil	
Central furnace	650
Floor or wall furnace	300

Enter the appropriate figure on Line 5 of Worksheet 6.

- *Pool heating:* See "Swimming pool heating," below.

Swimming pool heating

Many peop'e use more energy to heat their swimming pool than they do to heat their home. Unfortunately, you can't use your utility bills to figure out just *how much* energy, if your pool heating season and space heating season overlap—you need one month when you don't use either system. You can look back to the time before you had a pool. Subtracting your energy use then from your energy use now will give you a good estimate of what pool heating added to your gas consumption. If you can't do this, however, it's hard to obtain an accurate estimate. Calculating this energy requirement is extremely difficult and will probably require the assistance of an experienced solar designer or engineer. You could use an average fuel consumption figure, but it can range between about 1,100 and 1,600 therms a year, and any average figure may be way off in your particular case.

A rough estimate is better than none, however. The average annual natural gas use for pool heating in the PGandE service area is 1,350 therms. Allowing for burner inefficiency, this corresponds to a *Net Energy Use* of 945 therms per year.

Some people with swimming pools may want to determine their energy consumption for water heating and space heating as well. *In this case, use the worksheet(s) appropriate to your situation and enter 1,350 therms on Line 2c ("Other uses").* The resulting *Net Energy Uses* will be quite inaccurate if the assumed pool heating energy consumption is off in your case.

Part II: Energy Conservation

Now that you've figured out your current fuel use for water, space, and pool heating, the next step is to figure out how to *reduce* it. Though there are numerous approaches, we'll discuss mainly simple and inexpensive energy conservation measures that most people can use. We will also estimate the energy-saving potential of these measures and give you an idea of their cost. Worksheets are provided which enable you to calculate what reductions in your *Net Energy Use* for water, space, and pool heating you can expect from using the recommended measures. This reduced energy requirement – your *future* energy consumption – will be used to size your solar heating system in Chapter 5. For those of you who choose not to (or can't) use solar energy, the worksheets will still be of considerable value as they show you how and by what amount you could lower your present fuel use.

Reducing Your Energy Use for Water Heating

There are several measures which reduce the amount of energy used for water heating. In most cases, they involve only simple changes in your living habits or small expenditures of time and money. We'll discuss each measure – what's involved, its potential cost, and potential savings. As we go, we'll give you directions for filling out Worksheet 6. A sample completed Worksheet 6 is on page 34.

- *You should have entered your* Net Energy Use for Water Heating *here when completing Part I of this chapter.*
- Line 2: Energy conservation measures.

  a. *Reduce hot water use.* A low or no-cost means of saving energy on water heating (and saving water) is to reduce the amount of hot water you use. This can be done by some simple changes in hot water use habits. A five-minute shower uses about half as much hot water as a bath. For a few dollars (or perhaps even for free, courtesy of your local water utility), you can install flow-reducers in your shower heads and hot water faucets. With the appropriate detergents, clothes can be washed in cold water. If you wash dishes by hand, a cold water rinse may be sufficient; if you have a dishwasher, don't run it until it has a full load. Combining all these measures, a reduction of up to 50% in overall hot water use is possible. Estimate what percentage reduction you could achieve based on your current hot water use habits and what changes you intend to make. Convert the percentage to decimal form – for example 30% becomes .30. *Enter this reduction on Line 2a.*

  b. *Stop hot water leaks.* You can stop the silent (and sometimes not so silent) waste of water caused by dripping faucets. A single hot water tap leaking one drip per second can waste 10 gallons a day or 3,650 gallons of water a year. That alone can account for 10% of your hot water consumption if yours is an average four person family, 35% if you live alone. Change the faucet washers – it's an easy home maintenance job and costs less than a dollar if you do it yourself. Inspect all the hot water taps in your house or business to see if any are leaking. Once you know how many taps leak, you can estimate what energy savings you could achieve by fixing the leaks. If no taps are leaking, no reduction would occur. *Change your percentage savings to decimal form and enter it on Line 2b.*

c. *Add Lines 2a and 2b to get the total percentage reduction in your* Net Energy Use for Water Heating.

- Line 3: *Multiply Line 2c times Line 1 to determine the amount of the reduction.*
- Line 4: *Subtract Line 3 from Line 1.* The result is the reduced energy requirement (the *Annual Energy Demand for Water Heating*) that will be used to size your system in Chapter 5.

Other conservation measures

There are two additional ways you can make large reductions in your energy use for water heating. These measures will not reduce the amount of hot water a solar water heater must supply, as they affect only the standby losses, but they will save fuel and money.

- *Lower your water heater thermostat.* Large heat losses occur when hot water is "standing by" in your tank waiting for you to use it. You can reduce standby losses (and therefore the energy required to make them up) by turning down the thermostat on your water heater. If you set your thermostat halfway between low and medium (or at around 120°), the water temperature will still be hot enough for your hot water uses (except some types of automatic dishwashers), and you will reduce your standby losses up to 50%, depending on how high your present thermostat setting is.
- *Insulate your water heater tank.* Adding extra insulation on your water heater will also reduce standby losses. Wrap 3 1/2 inch thick fiberglass batts (available at your local building supply or lumber company) around the outside of the tank and fasten them with tape. Be careful not to cover either the top vent or the bottom air intake – the fiberglass won't burn, but its backing will. You can also buy a water heater insulation kit at major retail stores. The kit is safer and easier to install, but costs $20 compared to about $8 if you buy your own materials. Expect a reduction of up to 30% in your standby losses.

You can reduce your consumption of energy for space heating in much the same ways as you did for water heating. Here the savings will be even larger, because space heating (even in a mild climate, such as is found in the Bay Area) uses two to three times as much energy as water heating.

In general, you can reduce your energy use for space heating by putting less heat into your house, decreasing the flow of heat out of your house, and improving the efficiency of your furnace. We'll discuss measures that deal with each of these approaches, giving you instructions for filling out the rest of Worksheet 6 as we go. Refer to the sample completed Worksheet 6 to guide you.

In this section, we'll be asking you to do some "estimating" of your potential energy savings. If you want more information than we have included here, you can take a look at two other publications with more detailed procedures for determining your potential space heating energy savings. They are *In the Bank . . . or Up the Chimney* and the *Home Energy Savers Workbook* (references A-2 and A-3 in Chapter 8).

Continuing with Worksheet 6:

- Line 5: *You should have entered your* Net Energy Use for Space Heating *here when completing Part I of this chapter.*
- Line 6: Energy conservation measures.

  a. *Lower your thermostat.* If your thermostat is now set at 72° day and night, you are probably getting heat that you don't need. Gradually reduce the temperature until you find the lowest comfortable level. If you set your thermostat at 65° during the day and 55° at night, the annual energy savings (as opposed to a 72° day and night setting) can run as high as 35%, and it doesn't cost anything. Decide at what temperature you plan to set your thermostat, and estimate your percentage energy savings. *Convert this percentage to a decimal and enter it on Line 6a as your energy use reduction. Subtract from 1.00 to get the energy use remaining after the reduction. Enter the result on Line 6a.*

  b. *Stop air leaks.* If you do your own work, weatherstripping and caulking exterior doors and windows to stop air leaks will cost only about $2-3 per window and $3-5 per door. A plywood insert for your fireplace (when there's no fire) will keep warm air from going up the chimney and might cost about $5. You can expect combined energy

Sample Worksheet 6

Worksheet 6:

Reducing the Energy Used for Water Heating and Space Heating

Water Heating

1. Net Energy Use for Water Heating — 168 (1)

2. Energy conservation measures

	Energy use reduction	
a. Reduce hot water use	.30	(2a)
b. Fix hot water leaks	—	(2b)
c. Total		.30 (2c)

3. *Multiply Line 2c times Line 1.* — 50 (3)

4. *Subtract Line 3 from Line 1 to determine* your Annual Energy Demand for Water Heating. — 118 (4)

Space Heating

5. Net Energy Use for Space Heating — 634 (5)

6. Energy conservation measures

		Energy use reduction		Energy use remaining	
a. Lower thermostat	1.00	.20	=	.80	(6a)
b. Stop air leaks	1.00	.10	=	.90	(6b)
c. Insulate ceiling	1.00	.25	=	.75	(6c)
d. Insulate walls	1.00	0	=	1	(6d)
e. Insulate windows	1.00	0	=	1	(6e)

7. .80 (6a) × .90 (6b) × .75 (6c) × 1 (6d) × 1 (6e) = .54 (7)

8. *Multiply Line 7 times Line 5 to determine* your Annual Energy Demand for Space Heating. — 342 (8)

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savings of 25% or more if your house is presently drafty. Inspect your windows, doors, chimney, etc., and, on the basis of how much improvement they need, estimate the percentage energy savings you'd get if you caulk and weatherstrip. Convert the percentage savings to decimal form and subtract it from 1.00 to find the energy use remaining. *Enter these figures on Line 6b.*

c. *Insulate your ceiling.* You can insulate a 1,250 square foot ceiling for about $300, using 6" of fiberglass (R-19) or its equivalent. The cost will be slightly higher if you hire a contractor, but this measure alone can reduce your energy consumption by as much as 30%. On the basis of how much (if any) ceiling insulation you now have, estimate by what percentage your energy use could be reduced. Convert your percentage savings to decimal form and subtract it from 1.00. *Enter these figures on Line 6c.*

d. *Insulate your walls.* This is the most involved and probably most expensive measure. In most cases, you'll have to hire a contractor to insulate your walls (look in the Yellow Pages) at a cost of about 50¢ per square foot of wall area. Energy savings of up to 20% are possible, however. Depending on the amount and insulating value of the insulation installed, estimate the percentage energy savings possible, or get an estimate from an insulation contractor. *Enter this percentage in decimal form on Line 6d and subtract it from 1.00.*

e. *Insulate your windows.* There are a variety of ways to reduce the heat loss through your windows. The reduction could be significant since generally as much heat escapes through the windows as through the entire building wall area. Storm windows and other forms of double-glazing cut the heat loss through the windows about in half. See reference A-7 in Chapter 8 for instructions on making drapes that are effective window insulators. Insulated shutters closed over your windows at night will reduce the heat loss to a minimum, but are often difficult to add to an existing building. The cost range per square foot of window is considerable, from 10¢ for do-it-yourself plastic storm windows through $1 to $2 for do-it-yourself shutters, to $3 to $4 or more for draperies or contractor installed shutters or double-glazing. If every window were covered during the winter in some way, energy savings of up to 20% could be expected. Take a tour of your house or building and note how extensive the window area is. Determine what window insulation measures you could take before retrofitting for solar heating. Estimate by what percentage your heat loss could be reduced by these measures. *Enter this percentage in decimal form on Line 6e and subtract it from 1.00.*

- Line 7: *Multiply the energy use remaining figures from Lines 6a-6e together.* The result is the overall reduction in your *Net Energy Use for Space Heating* that will occur if you take these conservation measures.
- Line 8: *Multiply Line 7 times Line 5.* The result is the amount of energy (in therms) that a solar system would be required to provide to satisfy your estimated future demand for space heating. This is your *Annual Energy Demand for Space Heating* and will be used to size your system in Chapter 5.

Additional conservation measures

There are some additional measures for space heating that will save you money, but will not reduce the size of your solar heating system, as they conserve energy that is not provided by the solar system.

- *Service your furnace.* The efficiency of your existing heating system can be improved by having your furnace serviced. The cost is usually about $30. If it hasn't been done for a year or more, a complete servicing can reduce your next annual heating bill by about 10%.
- *Turn off pilot lights during the summer.* When your heating system is not being used, there is no reason to waste seven therms each month by leaving the furnace pilot light on. You can turn it off, referring to your furnace owner's manual for guidance. Retrofit electric ignition devices are also available that eliminate the pilot light altogether, saving you additional energy.

Reducing Your Energy Use for Pool Heating

There are two basic ways of reducing the energy used for pool heating: putting less heat into the pool and decreasing the heat loss from it. Specific measures follow, but no worksheet is provided because the estimates (where any are given) of reductions in pool heating energy use are less accurate and more difficult to make than those for water and space heating.

- *Lower your pool thermostat.* Let's begin with turning down the thermostat on your existing pool heater. Gradually reduce the temperature of the water in the pool until you find the lowest comfortable level. For each degree of temperature reduction, you'll reduce your bill by 4% to 8%, and at no cost.

  Combine lower water temperatures with a shorter swimming season and you'll really save energy. If you swim only during the summer and have lots of unobstructed sunlight on your pool, you generally can dispense with pool heating entirely and still enjoy temperatures in the 70's.

- *Cover your pool.* If you keep a properly-fitting cover on your pool except when you are swimming, you can expect energy savings of 30% to 75%. At a cost of between 15¢ and 65¢ per square foot, a pool cover will keep water temperatures in the 80's during the summer and 70's in the spring and fall. A transparent or translucent cover even allows some solar energy to heat the pool. In addition, side benefits of all covers are that you'll use less chlorine and water (because of reduced evaporation) and the pool won't need cleaning as often.

- *Build a windbreak.* In a windy location, a well constructed windbreak for your pool could save a considerable amount of the energy you now use for pool heating.

3: Solar Prospecting

Now that you have an idea of how much energy you need for heating and hot water, the next step is to survey your house or building to see where you can locate the various parts of a solar energy system. We call this "solar prospecting." Here you'll discover your building's potential for using solar energy, and gather information necessary to help you choose a retrofit system in Chapters 4 and 5.

Getting Oriented

Solar prospecting proceeds in this chapter in two stages. First, you'll use your common sense and some general rules to spot possible locations for solar collection areas. Second, you'll do measurements and calculations to make sure that your common sense is correct.

What are you prospecting for?

In theory, you're looking for places to locate all the parts of a solar energy system—collection area, storage, circulation, back-up, and delivery. But in practice finding a place for the collection area is by far the hardest. No matter what system you are going to use, its collection area must have acceptable orientation to the sun and receive plenty of direct sunlight. Storage and circulation are generally easier to fit into an existing building or yard, and depend in any case on the type of system selected, so we'll discuss them in Chapter 4. Back-up and delivery are generally provided by your existing water heater or space heating system. So, prospecting consists of two main tasks: finding and evaluating potential collection areas and taking note of your existing heating equipment.

The results of your prospecting will be recorded on Worksheet 7 ("Solar Prospecting"). A sample Worksheet 7 is shown on page 49. Most of the measurements must be made outdoors, where holding the worksheet along with the book and everything else might become a little awkward. So we've included places throughout the chapter to note measurements as you go. Later you can transfer all the numbers to Worksheet 7 and finish your calculations there.

Prospect thoroughly the first time

We suggest that you do a thorough solar survey, rather than checking only one or two possibilities, for two reasons. First, if you become fixed on one way of doing things, you may overlook an approach that could save you time and money. For instance, if you decide right off that your collection area has to be on your roof, you might never notice that south windows and some storage could be added in your family room more easily and at lower cost. Second, if you get all the information about your situation down on paper, it's easy to work through the rest of the book. You won't have to keep running outside to make more measurements. Of course, if you think of an additional solar possibility later, you can always come back and "prospect" it too.

Possible collection areas

Any generally south-facing wall, roof, or fence more than 30 square feet in area and receiving good sunlight can be regarded as a potential collection area, as shown in Figure 3-1. Ideally you want one rectangular, uninterrupted area large enough to do the job you want. It is possible to break the collection area up into two (or more) pieces, as we saw in Chapter 1 on the Heinemann house. However, for active systems this can lead to difficult design and low performance if the two segments do not work well together. Passive collection areas, such as drum walls, can be broken up with much less difficulty.

Some of the passive retrofits are easiest to do when you are remodeling at the same time—adding a room, a greenhouse, or pushing out a wall. If you are considering one of those possibilities, remember to make measurements and to estimate shading based on where the windows and walls *will be*, not where they are now. This can require a little imagination.

South-facing roofs are not the only candidate for flat-plate collectors. *Free-standing* collectors can also be mounted in yard areas, leaning against south walls, on flat roofs, and on low-pitched roof areas facing other than south. Figures 3-2, 3-3 and 3-4 show some of these options. Free-standing collectors get around some location problems, but they are not as easy to use as might appear. The following potential problems must be considered:

- *Visibility:* Free-standing collectors often protrude above the roof line of buildings, and are thus more visible than flush-mounted collectors.

- *Wind:* The panels can act as sails and tear off their mounts. To keep your collector where it belongs and to meet the building code, you need a structure capable of supporting a wind load of 15 or 20 pounds per square foot of collection area, depending on the height of your house. (Collectors generally weigh about 4-8 pounds per square foot.)
- *Earthquakes:* The panels must have sideways bracing capable of resisting two-tenths of their weight.
- *Chimney and plumbing vent clearance:* Free-standing panels can interfere with proper performance of chimneys and vents. Chimneys must extend two feet above any panels within eight feet. Plumbing vents must extend six inches above the panels. This could mean costly extensions to your chimney or vents.

These problems are usually not severe for free-standing collectors leaned against a wall or fence in the yard, but you must think things through carefully before using them on roofs. As with room additions, remember to visualize free-standing collection areas as they are actually to be built.

A warning about shading

Before you head outside to start finding possible collection areas, a few words are in order about shading. Shading rates right up there with a southern exposure in importance. Just as the collection area can't get sun if it doesn't have a southern exposure, a collection area aimed south but shaded at critical hours can't get much sun either. So forget any collection area that's mostly shaded during the winter months. If you want to do pool heating only, you'll need sun during the summer

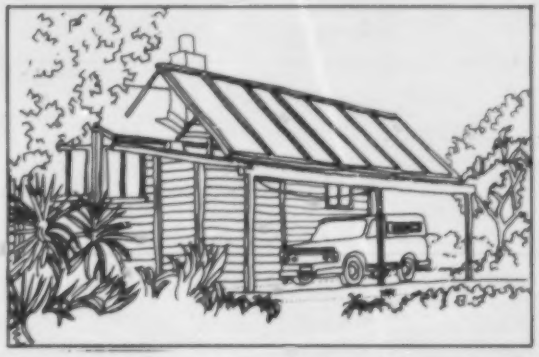


Figure 3-2: Free-standing collection area mounted over a carport.

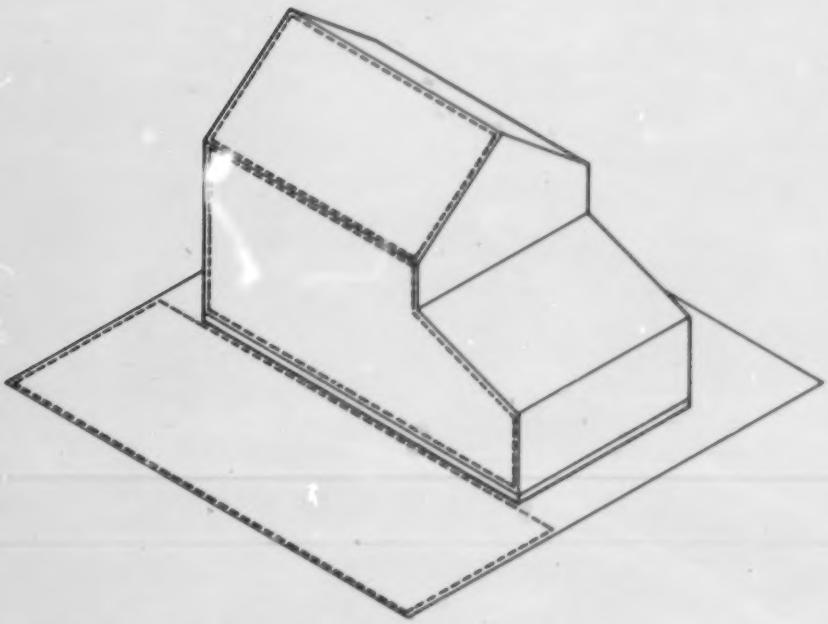


Figure 3-1: Any smooth, generally south-facing area should be prospected. The dotted lines indicate possible collection areas. We'll consider obstructions such as windows and vent pipes later in the chapter.

swimming season and may not have to take winter shading into account.

What about collection areas that are only partially shaded? Some shading during a few months is acceptable, but any significant amount can severely reduce your system's output. To understand why this is the case, remember, from Chapter 1, that when any sort of collector is operating, it both gains heat from the sun and loses heat to the surrounding air. In good sunshine, a collector gains more than it loses. When a portion of a collector is shaded, however, the gains on that area are cut off, but the losses continue. Thus, rather than simply having no effect, the shaded area actually reduces the total heat output of the collector. A shaded collection area is worse than no collection area there at all.

Figure 3-3: The roof on this house faces east and west, so free-standing collection area was installed against the south wall.

It's difficult to be precise about *how much* heat collection is reduced by shading. The penalty depends on the type of collector, its operating efficiency, the outside air temperature, and other factors. But a good rule of thumb is that whatever percentage of the collection area is shaded, the system will lose *double* that percentage in output. So if 10 percent of the collection area is shaded, the system's performance will drop 20 percent. If 50 percent of the collection area is shaded, the system may not deliver any heat at all!

Since shading varies over the year, one compromise people frequently make is to accept a small amount of shading during one or two months of the year. This is more practical for year-round water heaters than it is for winter-only space heating systems. After you have located possible collection areas, we'll get into how to estimate shading in more detail.

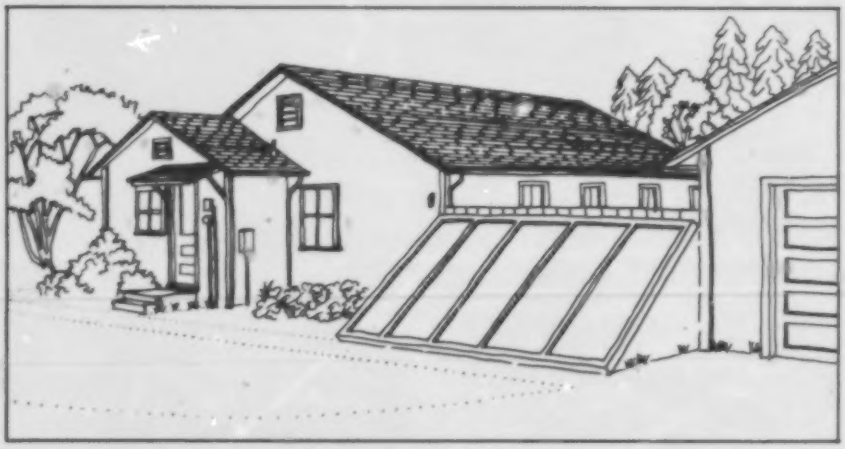


Figure 3-4: The fence between the house and the garage is used as support for free-standing collection area.

Finding south

Since you're looking for generally south-facing collection areas, the first thing you need to do is locate south. Extreme accuracy is not required, since you will be checking the orientation of each potential collection area later. Here are some ways to find south:

- *Compass method:* An inexpensive compass will give you an accurate fix on south. Take your readings somewhat away from the buildings, since any iron or steel in the walls will affect the operation of the compass. Remember also that magnetic south is not true south. In the Bay Area, true south is 17° east of the direction the south needle points.
- *Map method:* If you can, locate a plot plan or map of your property. South is shown on the map that usually accompanies your deed. A map of sufficient scale is probably available at your county or city building department. There are usually enough landmarks on these maps to enable you to get a fix on the location of your house. Also, you may be able to get the original plans for your house or building and these usually have a north-south arrow.
- *Solar noon method:* The sun is in a true south direction at solar noon. Solar noon differs from clock noon because of daylight saving, your location within a time zone, and other factors. Local solar noon can be calculated from sunrise and sunset times that are listed in most daily newspapers. Check your local paper and note these times. Solar noon will occur halfway between sunrise and sunset. At that time the sun is due south and a vertical stick will cast a north-south shadow.

After finding south, take some time to get an idea of how your building and property are oriented. Walk to several points on your lot and note landmarks (your holly bush, the neighbor's kitchen window, etc.) that are directly to the south of where you are standing. Notice the date, the time, and where the sun is in the sky. You'll quickly begin to develop a "sun-sense" for your property.

Now you are ready to pick some south-facing surfaces for detailed checking. Remember to include walls, garage roofs, and yard if they seem to be possible locations for collection areas. Write the location and type of each possible surface here:

Example: House roof

Surface 1: _____

Surface 2: _____

Surface 3: _____

Surface 4: _____

These will be transferred later to Line 1 of Worksheet 7.

Safety

As you check out locations for potential collection areas, you may have to do some ladder or roof climbing, so a few reminders on safety are in order.

Don't climb unless you absolutely have to. Often with a little ingenuity you can measure areas or estimate shading from the ground.

If you *have* to climb:

- Make sure your ladder is securely positioned before climbing up it.
- Never lean out from a ladder or over the house eaves. Position the ladder so you can get the measurements you need without extending yourself.

If you *have* to get up on the roof:

- Wear soft-soled, high-traction shoes such as sneakers.
- Watch where you're moving, both forwards and backwards. Better yet, don't move backwards at all. If you "just take a few steps backwards to get a better view," you may end up backing off the roof.
- Follow the hints given in Chapter 1 (page 17) in order to minimize the chance of causing leaks by walking on the roof.

Orientation

The first thing to check about a possible collection area is its orientation. As we saw in Chapter 1 on page 11, orientation is the number of degrees to the east or west of south that a surface faces. (The slope of the collector is another matter and will be discussed next.)

The general measurement you made to locate south may be sufficient to allow you to figure the orientation of a surface. For instance, you may have found that the frontage of your lot is just a few degrees off north-south and you know that your roof is parallel to the side of your lot (at right angles to the frontage). In this case, your roof has an orientation of about 0°.

Another possibility is that you plan to build free-standing collectors on a flat roof or in your yard. In this case it is often possible to orient the collectors due south (0° orientation). Sometimes, though, the shape of the mounting area, problems with vents and chimneys, or other difficulties prevent 0° orientation. So think through how you would mount free-standing collectors and calculate their actual orientation angle.

In many cases, it may be hard to "eyeball" the orientation of a surface. In that case, you can use the Orientation Calculator in Figure 3-5. Figures 3-5 and 3-6 explain how to use it. Note that the Orientation Calculator is already corrected for the Bay Area's deviation between magnetic south and true south, so it should not be used elsewhere. Remember that to measure the orientation of a roof, there is usually no reason to climb up on it. In most cases it is simpler to check a ground-level wall that is parallel to the roof in which you are interested.

If the south end of the needle points to the grey area on the Orientation Calculator, the surface you are considering is not recommended for water or space heating collection areas. Do not prospect it further. Note that *vertical* collection surfaces (walls) have a narrower acceptable orientation range than do roofs.

Pool heating collectors work well over a much larger range of orientation, as we will see in Chapter 4, because they are usually intended for summer operation, when the sun is high in the sky. Any orientation between 45° east of south and 90° west of south is acceptable.

Note your orientation measurements here:

Surface 1: _____

Surface 2: _____

Surface 3: _____

Surface 4: _____

Slope

The next thing to check is the slope of each possible collection area. In Chapter 1, we saw that the *exact* slope of a collection area is not important. Any surface tilted up more than 15° toward the south can be used. So, in this case, you can make a rough estimate. In fact, it is sufficiently accurate to simply "round off" the surface slope to one of several standard slopes. Use Figure 3-7 to select the standard slopes that best fit the surfaces you are prospecting. Note that on a low-pitched roof you can mount the collection area either flush to the roof or free-standing above it. The steeper free-standing collectors will capture more sunshine per square foot, but this added output may not be worth the potential problems discussed on pages 37 and 38. You may want to prospect low-pitched room areas both ways and make your choice later.

Enter the "rounded off" slopes of the surfaces here:

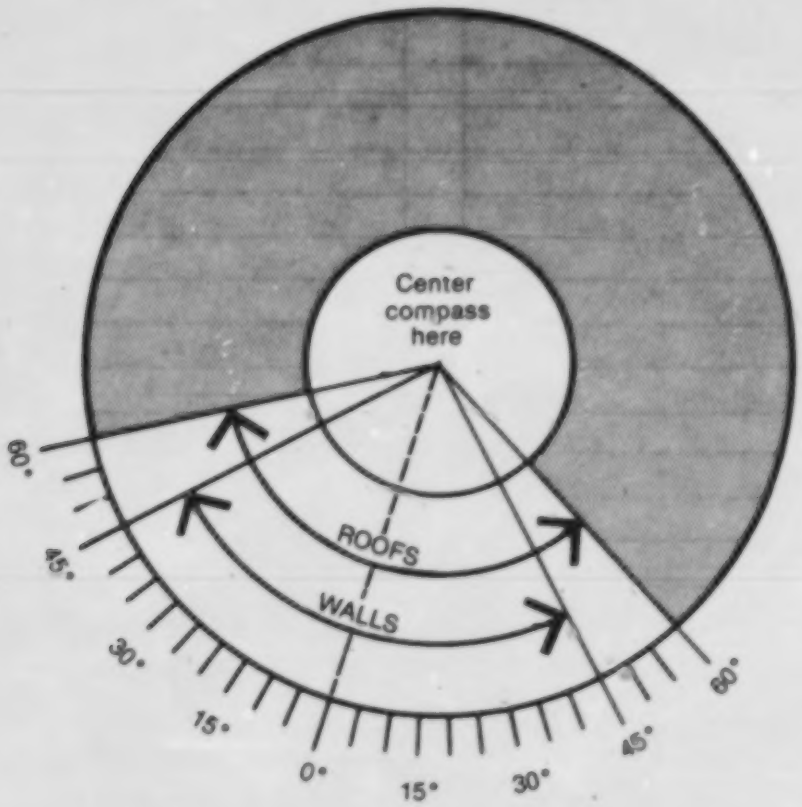
Surface 1: _____

Surface 2: _____

Surface 3: _____

Surface 4: _____

Place this side of the book against the wall you want to measure.



ORIENTATION

Figure 3-5: Orientation Calculator. See Figure 3-6 for instructions on how to use the Calculator. If the south end of the needle falls in the shaded area, do not consider using the surface being measured as a collection area for space or water heating. Otherwise read the orientation in degrees. Note that walls more than 45° from south are not recommended for collection area.

Figure 3-6: Place a compass on the center of the Orientation Calculator (Figure 3-5). Hold the book level with the top of the page flush against the wall you want to measure. The south end of the needle points to the orientation of the wall.

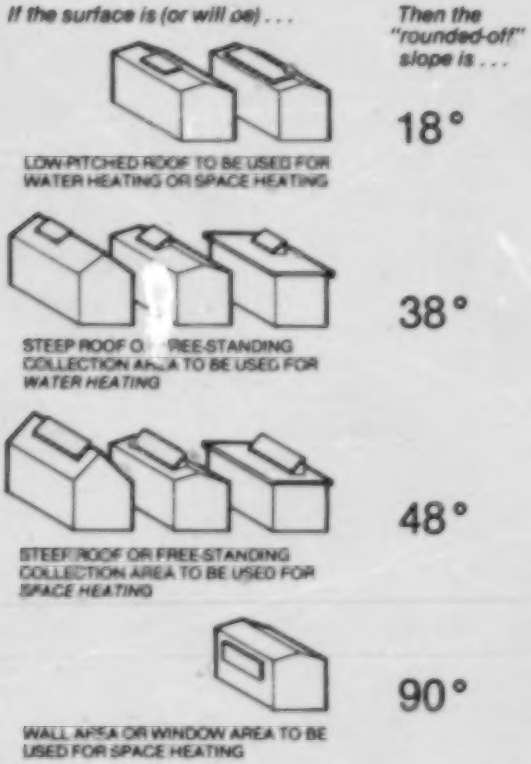

If the surface is (or will be) . . .
Then the "rounded-off" slope is . . .
LOW-PITCHED ROOF TO BE USED FOR WATER HEATING OR SPACE HEATING
18°
STEEP ROOF OR FREE-STANDING COLLECTION AREA TO BE USED FOR WATER HEATING
38°
STEEP ROOF OR FREE-STANDING COLLECTION AREA TO BE USED FOR SPACE HEATING
48°
WALL AREA OR WINDOW AREA TO BE USED FOR SPACE HEATING
90°

Figure 3-7: Select the "rounded-off" slopes that best fit the surfaces and uses you are considering.

Obstructions and other problems

Now you should note any obstructions that might prevent you from installing collectors or from modifying a wall for a passive retrofit. Figure 3-8 shows examples of things that could give you problems. Obviously, if you are considering adding a greenhouse or installing additional windows, you would not consider existing windows "obstructions." On the other hand, windows might get in the way of tube walls or other systems mounted on the south wall.

Some obstructions are relatively easy to move. For instance, drainage downspouts can usually be relocated with only a few hours work. Some plumbing vents can be easily moved, while others present tremendous problems. Consult a builder or plumber if you have questions about moving obstructions.

Other sorts of problems may prove to be "obstructions" as well. Here are some things to consider:

- *Zoning.* Some projects, especially room additions and greenhouses, may be regulated by zoning restrictions in your area. Check with your city or county to find out about setbacks, height restrictions, or other regulations. Some areas also have architectural review boards that must approve your plans.
- *Aesthetics.* Now's the time to cross that bridge. Are you willing to alter the appearance of your house or building? Most solar retrofits will be noticeable. In Chapter 4, we will see specific examples. But if there is a surface that you are not willing to change, you should rule it out now.
- *Working conditions.* An otherwise perfect collection surface is worthless if it is too difficult to do the required construction work on it. Any slope steeper than 30° requires time-consuming safety precautions, and it is difficult to get materials to high or inaccessable surfaces.
- *Existing roof material.* It's difficult to fasten collectors to slate or tile roofs. Wood and asphalt shingle roofs present fewer problems.

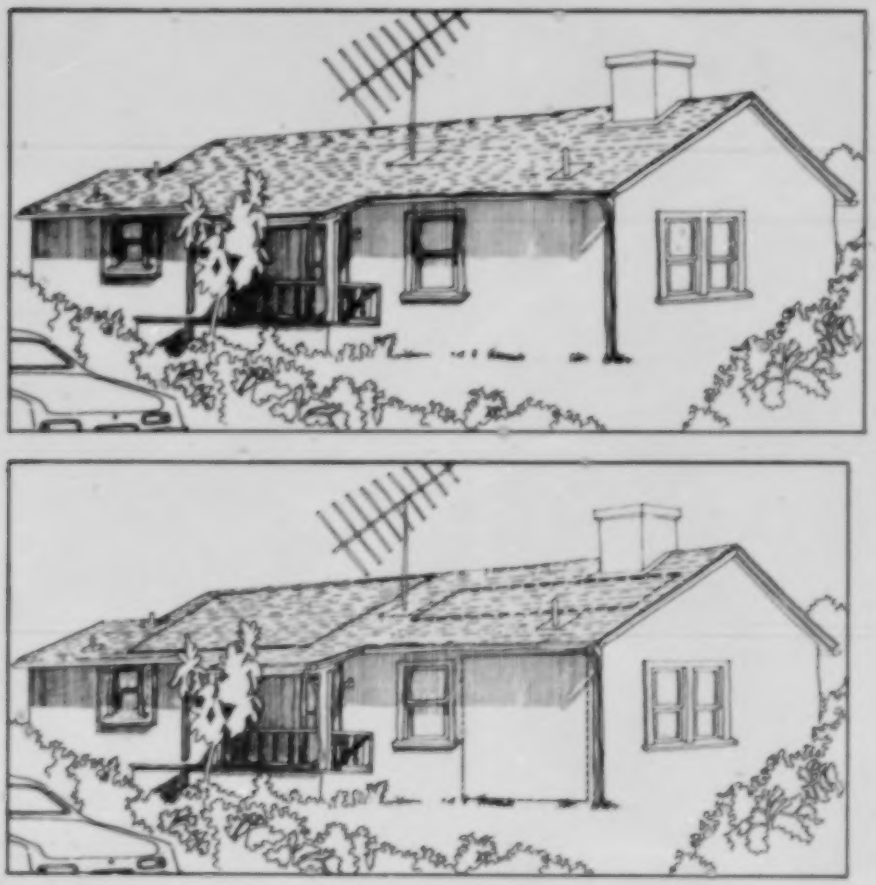


Figure 3-8: **The obstructions on the roof and wall of this house limit the possible collection areas to the ones outlined with dotted lines.**

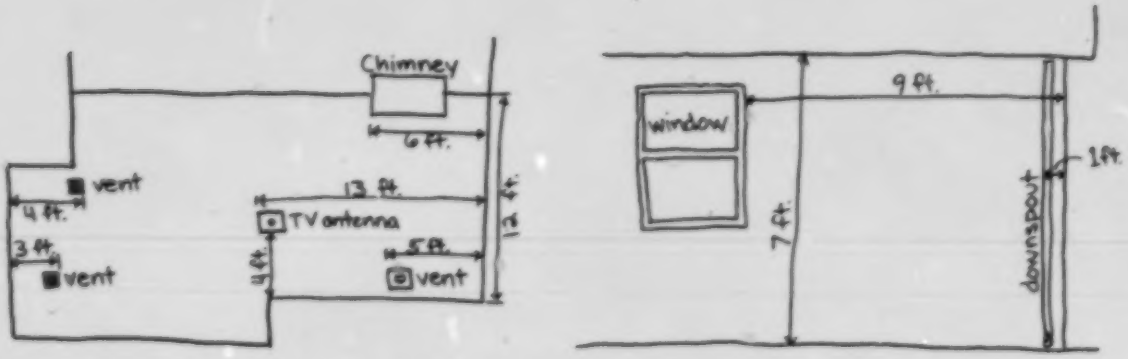


Figure 3-9: **Example surface sketches of the south-facing roof and wall of the house shown in Figure 3-8. All obstructions and measurements to locate them are shown.**

Make sketches

You should now make a sketch like the one in Figure 3-9 for each surface still in the running as a possible collection area. Measure the overall dimensions of each surface and include them on the sketch. Also show any permanent obstructions, with measurements that locate them as exactly as possible. Make the sketch large enough (8 1/2 x 11 inches) so you can add shading information later. And remember to show the surface as it will be, rather than as it is now, if you are planning to change your building.

Shading

There are two kinds of shading that must be considered. First, buildings or trees to the south can cast shadows on your collection area. This kind of shading is worst in the winter, when the low sun casts long shadows. Second, tall overhanging trees or building eaves can cast shadows during the summer, when the sun is high.

When checking for shading, always try to anticipate future problems. A tree could grow several feet in only a few years or your neighbor could build an addition onto his house. Since you presently have no legal right to sunlight, you have to protect yourself by not installing a collection area where it might be shaded in the future.

In some cases, it is immediately obvious that there are no shading problems – there just isn't a tree or building within sight. Most cases, however, are more complicated and you'll have to figure out what portions of possible collection areas are shaded. Small shadows cast by a telephone pole or leafless branches aren't serious, but large, solid shadows can be disastrous.

The "wait-and-see" method

The simplest and most reliable method for estimating shading is to "wait and see." Once a month or so, on a sunny day, check the potential surfaces at 9 a.m., noon, and 3 p.m. Make notes and sketches (or take snapshots) to keep a record of any shading problems. Be sure to write the times and dates on each.

In theory, you should check shading during the entire season when you want your system to operate – winter for space heating, all year for water heating, and summer for pool heating. In most situations, though, a one-day check around December 21 is sufficient, as the sun is lowest in the sky at that time of year. In cases where overhanging shading could be a problem, checking over a longer period is required. It is rare that you would ever need more than three to six months to get the complete picture. This is because the sun's position in the sky cycles between low in December and high in June. Pairs of intermediate dates have about the same shading conditions, as follows:

Date(s)	Sun position
December 21	Lowest
Jan 21 and Nov 21	
Feb 21 and Oct 21	
Mar 21 and Sept 21	Midway
Apr 21 and Aug 21	
May 21 and July 21	
June 21	Highest

You get information for two dates from most of the shading observations you make.

The Solar Viewer method

A faster, but less accurate method to check shading is to use the solar Viewer, which you can make according to the instructions on page 128. Assemble and use the Viewer according to the instructions.

The Solar Viewer has the advantage that it can be used at any time during the year. When it is held up to your eye (as shown in Figure 3-10), pointed due south, and held level, the lines show the approximate path of the sun across the sky on various days of the year. Figure 3-11 shows a typical view.

The Solar Viewer only tells you about shading at the spot you are checking – that is, at the location of your eye. If you can do so safely, kneel down when using the Viewer to bring your eye level as close as possible to the spot you are checking. To estimate shading on the entire surface you are prospecting, you need to check several points along its southern edge. Since shadows come from the south, the lowest, southern-most edge of a surface will be shaded if any part is.

On the ground or on a flat roof, checking several spots with the Viewer is easy and safe, as long as you don't try to walk around while actually sighting. Sloping roofs are much more dangerous, and we do not recommend using the Viewer on them. In some cases you can get good sightings out of windows just below the eaves; in others, a step ladder may be tall enough to check shading safely.

If there is some shading, make more spot checks to locate the boundaries of the shadow at various times of the day and year. This may be impossible to do on a roof, and you may have to resort to the "wait-and-see" method. If you can get sightings, make notes and sketches showing where the shadows are.

Estimating shading from overhangs

The Solar Viewer doesn't give you any help in estimating shading from overhanging trees or eaves – that is, the summer shading problems. You'll have to use the "wait and see" method for any complicated situations here.

Noon time eave shading for walls oriented within a few degrees of south can be estimated with the help of Figure 3-12 and the following table:

Date(s)	Factor
Dec 21	.5
Jan 21 and Nov 21	.6
Feb 21 and Oct 21	.9
Mar 21 and Sept 21	1.3
Apr 21 and Aug 21	2.0
May 21 and July 21	3.1
June 21	3.9

On the dates shown,

Overhang x *Factor* = *Shadow Length*.

For example, a 3 ft. overhang would, at noon on Sept 21, cast a 3 x 1.3, or 3.9 ft. shadow on the wall.

When you have gathered shading information for each possible surface, add it to the sketches you made of each surface. Figure 3-13 shows how a sketch might look now.

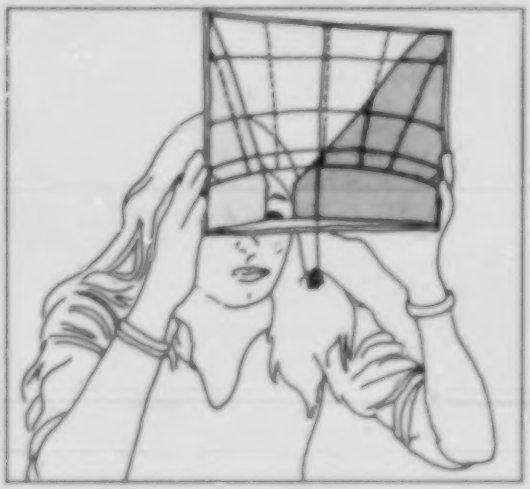


Figure 3-10: Using the Solar Viewer. Note that eye level is even with the bottom of the Viewer. Face south and hold the Viewer level, as indicated by the string-and-paperclip level indicator. Move your eye around to check shading at different times of the day and year.

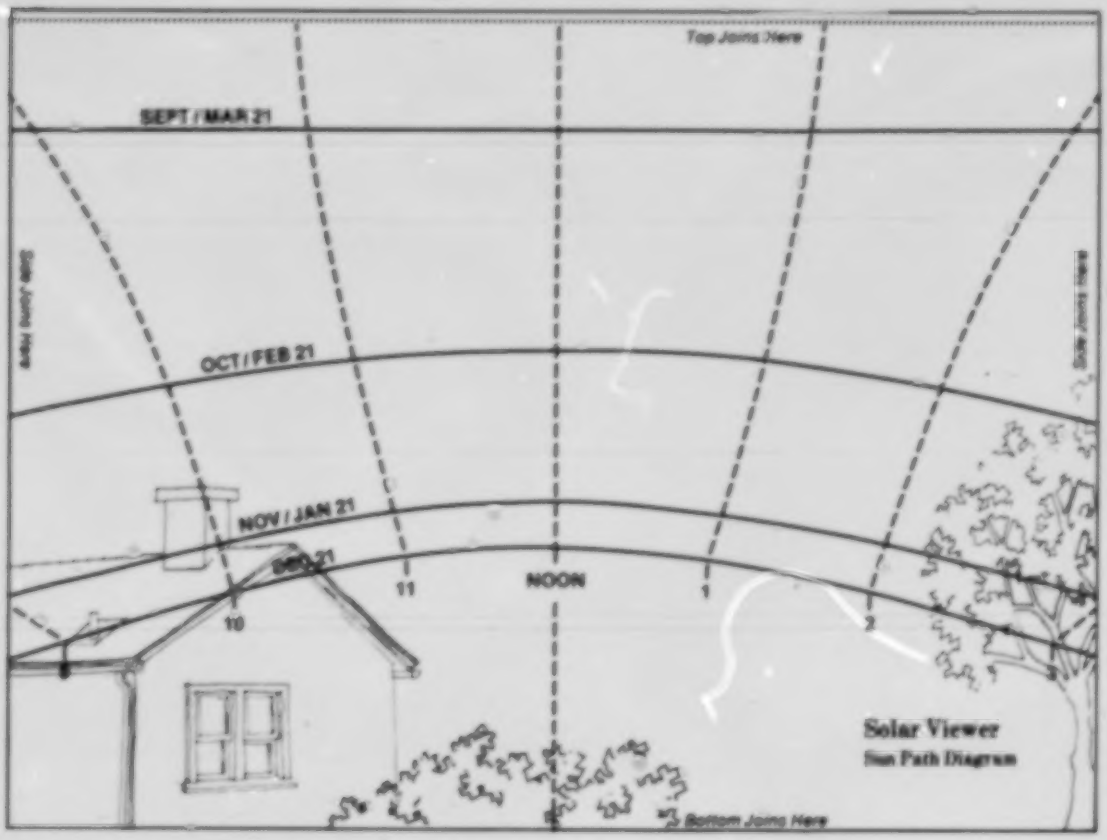


Figure 3-11: Typical scene through the Solar Viewer. On December 21, the sun is behind the house until 10:30 AM and goes behind the tree at 2:30 PM. On October 21 and February 21, there is full sun until about 2:30 PM. In September and March there is no shading between 10 AM and 2 PM. Unless there are overhanging trees, there is no shading throughout the summer.

Figure 3-12: Estimating eave shading. The OVERHANG is the horizontal length of the eaves, not their length along the roof slope. The SHADOW LENGTH is the length of shading below the point on the wall even with the bottom of the eaves. Use the method explained in the text to calculate the SHADOW LENGTH on different days of the year.

Filling Out Worksheet 7

Now that you've done all the outdoor work, you can sit down at the kitchen table with your notes, sketches, and a cup of coffee, and begin the second stage of solar prospecting. Refer to the Sample Worksheet 7 for help as you go along.

Begin by making the following entries on your blank copy of Worksheet 7:

- Lines 1-3: *Copy your prospecting notes and measurements onto these lines.*
- Lines 4-5: *Summarize the obstruction and shading situation for each surface here.*

You are now ready to calculate how much of each surface is usable as collection area.

Usable Area

For each potential collection area, use your sketch to figure the length and width of the unobstructed, unshaded area. At this point, go ahead and include portions of the area that might be partially shaded. In Chapter 5, you will calculate how much area you actually need, and partially shaded areas can be eliminated at that time if you can get by without them. Figure 3-14 shows how to use a surface sketch to estimate an area's length and width.

- Line 6: *Enter the length and width of each area.*
- Line 7: *Multiply in each case to get the gross area.*

Free-standing collectors do not necessarily have the same area as the roof on which they are mounted. Also, when two or more rows of free-standing collectors are used, they must be installed with enough spacing between the rows that they don't shade each other. Figure 3-15 explains how to calculate adjustment factors to correct the gross area, if necessary, when free-standing collectors are used.

- Line 8: *Enter the Free-standing Factor, calculated from Figure 3-15, for each area. If the collection area will be flush with the surface, the factor is 1.*
- Line 9: *Multiply Line 8 by Line 7 in each case to get the Usable Area.*

The Usable Area is the maximum collection area that you could install on a surface.

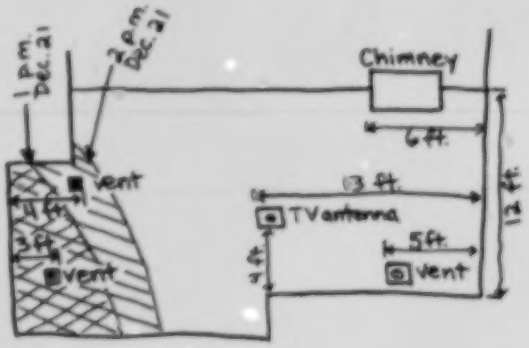


Figure 3-13: Example surface sketch with shading information added.

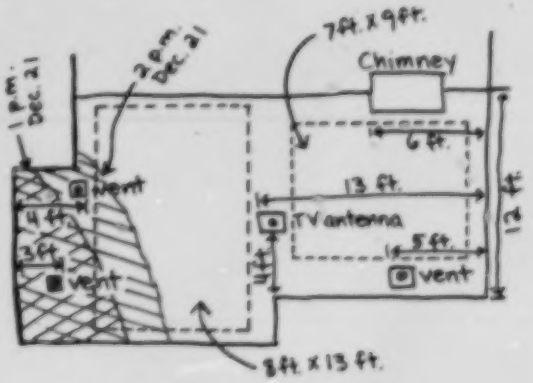


Figure 3-14: Usable Area resulting from the conditions shown on the surface sketch. Allow 1 or 2 feet of clearance from obstructions. Select large, clear rectangular areas, as shown. Include areas that are partially shaded — you're trying to estimate the sizes of the *largest* collection areas you could install.

Sample Worksheet 7

Worksheet 7: Solar Prospecting

	Surface 1	Surface 2	Surface 3	Surface 4
1. Location and type	house roof	house wall		
2. Orientation	10°	10°		
3. Slope	18°	90°		
4. Obstructions on surface	†antenna vents	downspouts		
5. Shading of surface	afternoon Dec	bottom of wall		
6. *Enter length and width of unobstructed, unshaded area.*	7x9 8 x 13	7 x 8	x	x
7. *Multiply to get gross area.*	167	56		
8. *Enter Free-standing Factor.*	1	1		
9. *Multiply to get Usable Area.*	167	56		
10. *Enter Orientation/Frame Factor.*	85	.85		
11. *Multiply to get Effective Area.*	142	48		

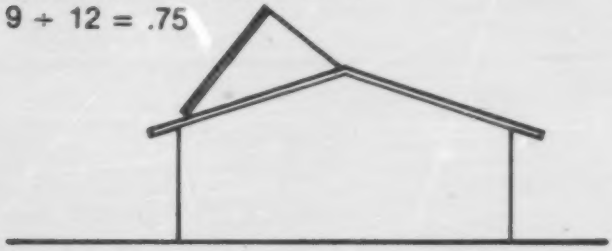
12. Existing equipment

12a. Water heater type and location: electric, in garage

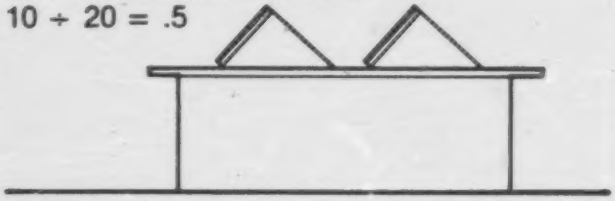
12b. Furnace type and location: natural gas — central furnace in utility room

FREE-STANDING FACTOR = LENGTH OF COLLECTOR ÷ LENGTH OF SURFACE

LENGTH OF COLLECTOR = 9 FT.
LENGTH OF SURFACE = 12 FT.
9 ÷ 12 = .75



LENGTH OF COLLECTOR = 5 FT. + 5 FT. = 10 FT.
LENGTH OF SURFACE = 20 FT.
10 ÷ 20 = .5



LENGTH OF COLLECTOR = 11 FT.
LENGTH OF SURFACE = 8 FT.
11 ÷ 8 = 1.4

LENGTH OF COLLECTOR = 4 FT.
LENGTH OF SURFACE = 8 FT.
4 ÷ 8 = .5

Figure 3-15: **Calculating the Free-standing Factor. For flush-mounted collection area, the Free-standing Factor is 1. For situations where you are considering free-standing collectors, draw cross-section sketches like the ones shown here. Divide the length of the collector by the length of the surface to get the Free-standing Factor. Each case is different, but in most cases, the Factor should come out between .5 and 1.5.**

Effective Area

Because of collector frames and space requirements for pipes, the collection area is smaller than the Usable Area. As a rough estimate, we recommend using 85% of the Usable Area as the absorber area. Therefore a frame correction factor of .85 is required here.

The Usable Area must also be corrected for off-south orientation. The Performance Charts in Chapter 5 are based on due south orientation. Systems with orientations other than due south will perform as if they were smaller systems, so an orientation correction factor is required here as well.

We have combined the two correction factors into the Orientation/Frame Factor. The following table lists this factor for vertical and sloped surfaces of various ranges of orientation:

	Orientation/Frame Factor	
Orientation (from Line 2)	Vertical Surfaces	Sloped Surfaces
0° - 15°	.85	.85
16° - 30°	.80	.80
31° - 45°	.70	.75
46° - 60°	—	.70

- Line 10: *Enter the Orientation/Frame Factor from the above table for each surface. Look to Line 2 for the Orientation. For example, a sloped surface with an orientation of 33° has an Orientation/Frame Factor of .75.*
- Line 11: *Multiply Line 9 by Line 10 to get the Effective Area for each surface. Note that the Effective Area is used only for performance calculations in Chapter 5.*

The final solar prospecting task is to familiarize yourself with your existing heating equipment. The details of whether and how to hook into your present equipment depend on the type of retrofit solar heating system you choose. By looking over your existing equipment, you'll prepare yourself for dealing with these matters in Chapter 4. Check the equipment that applies in your case, as follows.

Water heater

Locate your water heater and note whether it runs on electricity or gas. Look over the plumbing layout of your house. Pay particular attention to the route of the cold water supply pipe coming into the water heater, since you may want to interrupt it to install a solar water heater. Note the type and location of your water heater on Line 12a of Worksheet 7.

Heating system

There is much more variation in space heating systems than there is in water heaters. Note what type of fuel your existing system uses and how it works. Some systems, such as floor furnaces, wall furnaces, and electric baseboard units, simply deliver heat directly. There is no way to tie a solar system into this sort of equipment. On the other hand, central heating systems, such as forced air furnaces or radiant floor slabs, can usually be adapted to solar. If you have a central system, note the following:

- *Forced air systems:* Locate the supply and return ducts. Look at the possibilities for installing additional equipment on the return side of the furnace. We will discuss specifics in Chapter 4.
- *Water (hydronic) systems:* Trace the pipe runs (the visible ones, at least) and figure out how the water is pumped around your house. Examine your boiler and note how it connects into the system.

For the record, write the location and type of your existing space heating system on Line 12b of Worksheet 7.

Pool heating

Look at your filter, pump, and heater. Figure out how the pool water is pumped through the system. Locate the pipe runs going to and from the pool.

Onward

You now have a good idea of the solar retrofit potential of your house or building. If your solar prospecting has revealed some possible collection areas, you're ready to move on to Chapter 4. It describes the many types of solar systems suitable for retrofitting and shows you how to match the systems with the available collection area of your house or building.

If there isn't any place to use as collection area, you cannot do a solar retrofit. Remember, however, that you can still save a great deal of energy by applying the conservation measures discussed in Chapter 2. And you might continue reading through the rest of the book for general information. If you plan to move, do a little solar prospecting before you buy — then you won't be stuck in that position again!

4: Retrofit Systems

Now let's take a shopping tour of possible retrofit systems. In the following sections, we present twelve basic systems that are representative of what's currently available and practical for use in the Bay Area. We describe each system, explain how it works, and discuss how it can be installed in an existing house or building. Near the end of the chapter, there is a Comparison Table that gives cost figures, collector mounting locations, do-it-yourself possibilities, and other information about each system. After you've gone through the whole chapter, use the Comparison Table to help in choosing a system.

Remember that each system has its strong points, but one is not necessarily better than another in all situations. Choosing a system is a matter of finding a match for your needs, your building, and your budget. It is much like choosing a house or a car.

When you have picked a system (or several candidates), you can go on to Chapter 5 and estimate how much energy you can expect the system to provide. Then you can match the size of the system to the building's Usable Areas you located in Solar Prospecting. It may take you several tries to find a combination that suits you.

The drawings and diagrams included with each system description are intended to show the parts and principles of the system's operation. *They are not blueprints!* Many engineering details concerned with plumbing, ducting, and construction have been omitted for simplicity.

The systems we present include three types of water heaters, eight types of space heaters, and a basic pool heater. They are:

- *Water heating systems:* "Breadbox," flat-plate, and commercial.
- *Space heating systems:* Windows, drum wall, tube wall, Trombe wall, attached greenhouse, no-storage air heaters, and flat-plate systems using air and water.
- *Pool heaters:* Standard unglazed.

Solar Water Heating Systems

Water heating is an ideal task for solar energy. We'll discuss three types of water heaters, which have these common features:

- Since the water heated by the solar collectors is used directly, their designs are straightforward, and they are relatively inexpensive.
- You need hot water year round, so a solar water heater never sits idle, as a heating system often does during the summer. This means your investment in solar equipment is continually producing fuel savings.
- Solar water heaters supply a varying percentage of the total water heating energy requirement, but, because of your existing water heater, hot water is guaranteed. Cold water goes first to the solar heater and then to your existing heater, which now serves as a back-up. On sunny days, the solar heater heats the water to a high temperature, leaving the back-up with little or nothing to do. On less sunny days, the solar heater does a smaller percentage of the heating. Even on cloudy days, it can sometimes warm water a few degrees.

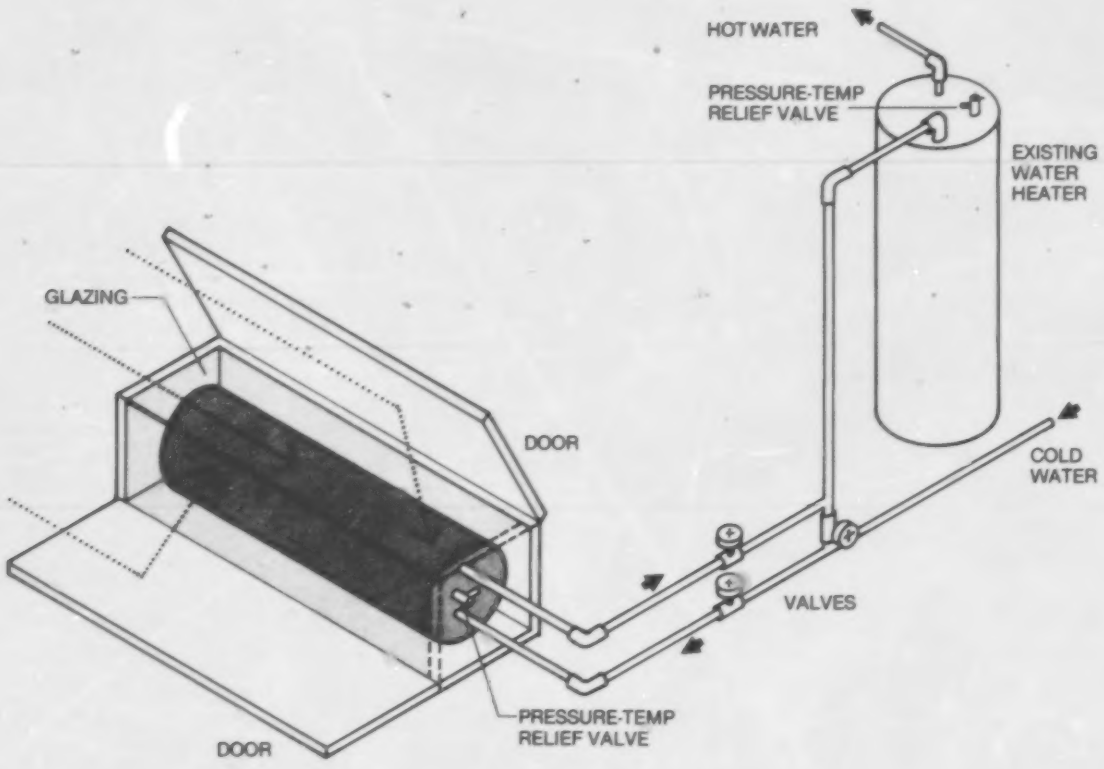
Thus, water heating is a sensible retrofitting project to start with. A solar water heater will save you more fuel per dollar invested than will a solar space heating system — and the investment required is much less.

"Breadbox" water heater

If you've ever watered your garden using a hose that's been lying in the sun, you've experienced a simple solar water heater at work. Obviously the short spurt of hot water produced wouldn't get you through a shower or a load of laundry, but the way it is produced illustrates the basic principle of *storage-type* solar water heaters. If you put a container full of water out in the sun, it will get hot.

Storage-type water heaters work simply by letting the sun shine on a combined collector-storage tank of some kind, unlike systems that heat water by continuously circulating it through a flat-plate collector. The simplest storage-type water heaters are coils of black plastic pipe or black polyethylene bags filled with water and set out in the sun. Like the garden hose, however, these heaters have an obvious shortcoming: the water in them cools off rapidly after the sun goes down. If you're willing to pattern your use of hot water around the availability of sunlight, however, these simple heaters are about the most cost-effective systems possible.

Figure 4-1: The breadbox water heater. The sunshine heats the water in the tank. Extra sunshine is reflected onto the tank by the shiny surfaces on the insides of the doors. When a tap is turned on, hot water flows from the breadbox tank into the existing hot water heater and cold water enters the breadbox tank. The existing heater boosts the water temperature if necessary. The doors are closed at night to keep the water in the breadbox tank warm. The valves allow the removal of the breadbox for repairs. The breadbox tank should be glass-lined for durability and should be protected by a pressure-temperature relief valve.



Putting an insulated, glazed-top box around the storage tank lessens the overnight heat loss. Glazed storage-type solar water heaters were used extensively in California during the 1930's and are common today in Japan. The design was recently refined by Zomeworks Corporation of Albuquerque, New Mexico; they added insulated, reflecting doors to the box, as shown in Figure 4-1. The doors further cut heat losses at night and also bounce extra sunshine onto the storage tank. This design is known as the "breadbox" water heater.

As shown in Figure 4-2, the breadbox should be installed in a sunny, south-facing location beside your house, as near as possible to your existing water heater. The cold water pipe to your existing heater is interrupted so that the water on its way to the heater is rerouted through the breadbox, as shown in Figure 4-1. Instead of feeding your regular water heater with cold water directly from the city mains, you're feeding it solar warmed water.

Because of their weight (about 500 pounds for a 50 gallon tank), breadboxes can't be casually perched on top of your back porch. They're much more suited to ground-level installation. If shading problems preclude putting a breadbox in your yard, be sure to consult a structural engineer about proper support and earthquake bracing before mounting it in a high location. Also, remember that you must be able to open and close the doors, so the mounting place must be accessible.

Constructing a breadbox requires primarily plumbing and carpentry skills, tools, and materials. No large amount of cash is required – a typical breadbox can be built with store-bought materials for about $400, and it's possible to reduce this amount substantially by using recycled materials. Good do-it-yourself plans are available from Zomeworks and McCracken. Their addresses are listed in Chapter 8, references E-1 and E-2.

There's also a bargain basement variation on the standard breadbox design which involves using an old refrigerator. Line the inside with aluminum foil, lay the water tank inside it, cut holes for the pipes, and put a sheet of glazing across the front of the refrigerator, inset far enough so that the door can be shut. When opened to the sun, this arrangement will collect solar energy well, and the insulation already in the refrigerator body and door will cut the heat loss at night. (Safety reminder: Since it may be a while before you get the breadbox built, be sure to remove the latch from the refrigerator door so a child can't climb in and get trapped.)

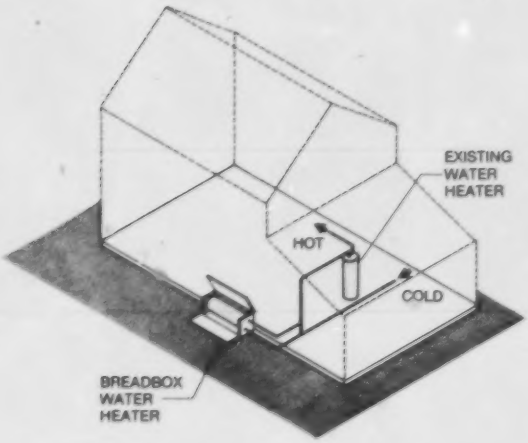


Figure 4-2: **A breadbox water heater on the south side of a house. Note that the exterior pipes must be heavily insulated to prevent them from freezing on cold nights. The tank itself will not freeze.**

Flat-plate water heater

This solar water heater can be used on homes or small businesses. A complete package, consisting of collectors, tank, pump, and controls, can be purchased off-the-shelf. As we will see in the next section, this system can be readily scaled up to meet commercial hot water needs.

A relatively small area of flat-plate collectors (30 to 100 square feet) is required for household water heating. The collectors are generally mounted flush on the roof (see Figure 4-3). In the Bay Area, the ideal slope for the collectors is 38° from horizontal, but any slope between 15° and 45° performs well. Free-standing collectors can be used on flat or low-pitched roofs or in other mounting locations.

A storage tank is required with a capacity of about 1.5 to 3 gallons per square foot of collector. Tanks of this sort look like conventional water heaters, but are somewhat larger. The ideal place to install the tank is next to the existing heater; however, when there is not enough space to do this, it may be located elsewhere, often with only a little extra plumbing. Figure 4-4 describes the operation of a solar water heater, and Figure 4-5 shows how one is installed in a house.

A flat-plate water heater does not necessarily have to use a pump to move water from the tank to the collector. If the storage tank can be placed *above* the collector, then the pump and controls can be eliminated. This is a *thermosiphon* system, as explained in Figure 4-6. In existing buildings, it is sometimes possible to locate the solar tank on the second floor or in the attic. Usually, however, the weight of the water requires so much support and earthquake bracing that suitable high locations are difficult to find. As with the breadbox water heater, consult a structural engineer before proceeding. While thermosiphon systems are more efficient than pumped systems, they have another drawback: they require larger (often 1 1/4 inch diameter) piping between the collector and storage than that used in pumped systems, which can add considerably to the system cost.

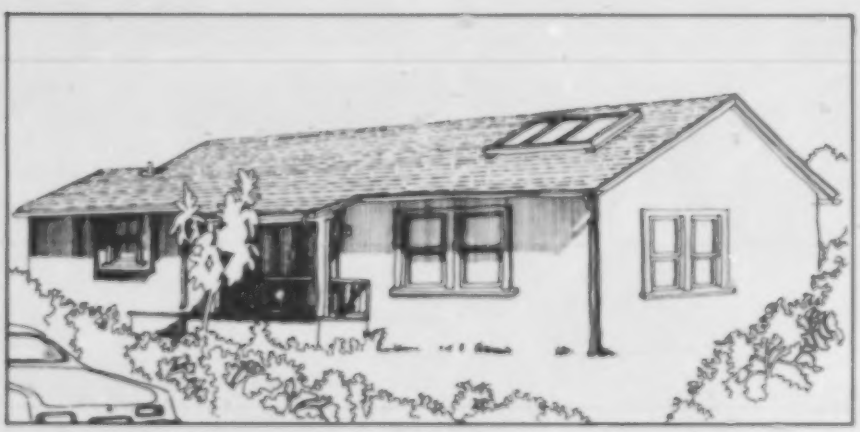


Figure 4-3: A house with a retrofit solar water heater. The small flat-plate collector is mounted flush on the roof.

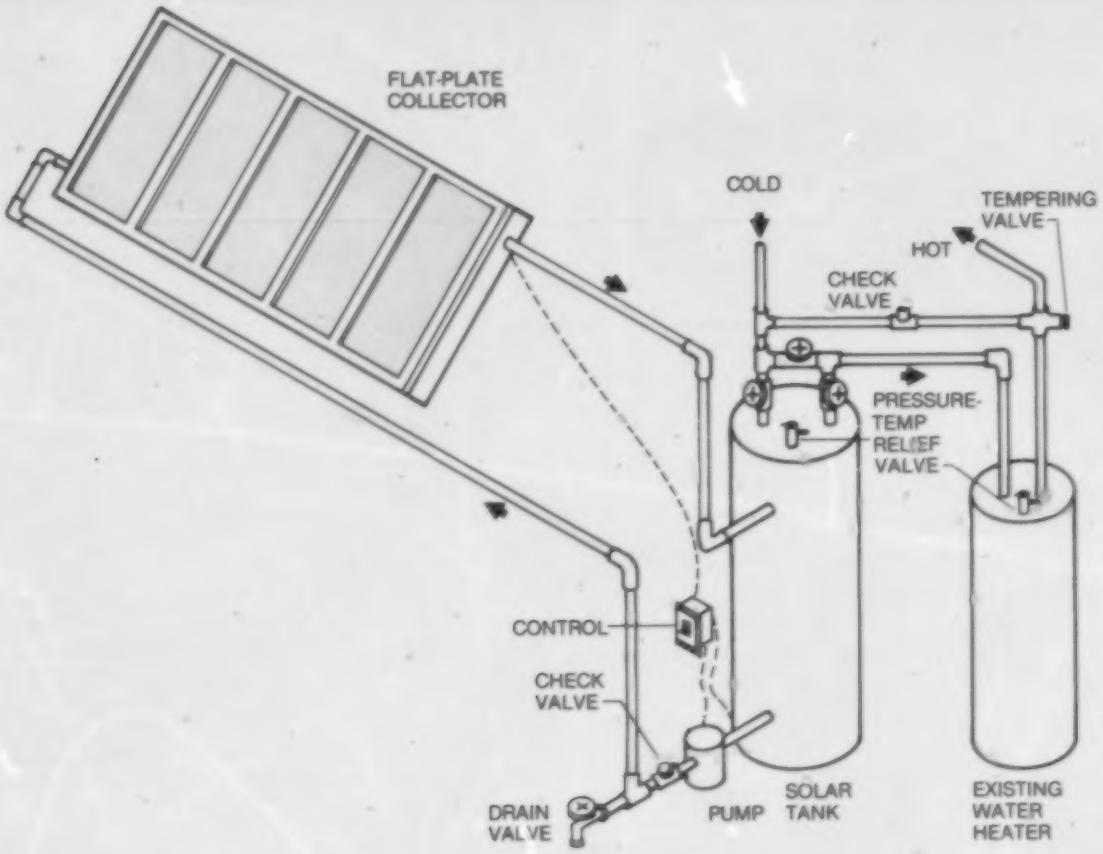


Figure 4-4: Schematic of a flat-plate water heater. The control activates the pump when the collector is warmer than the tank and this circulates water through the collector and back to the tank. The check valves prevent reverse flow of water; the drain valve allows the solar tank to be drained; and the tempering valve prevents dangerously hot water from going to the taps by mixing in cold water when necessary. Note that the solar tank and the collector are part of the plumbing system. This means the solar tank must be glass-lined and the collector must have copper tubes to prevent corrosion.

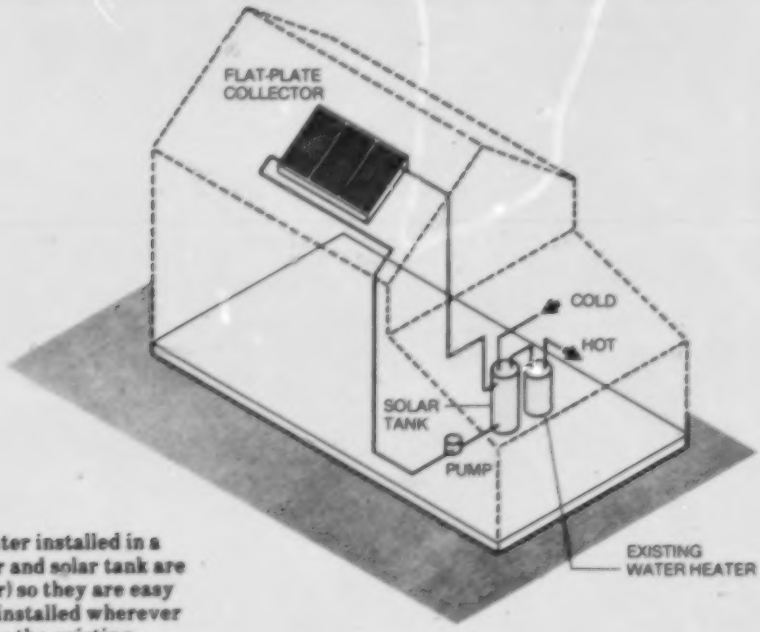
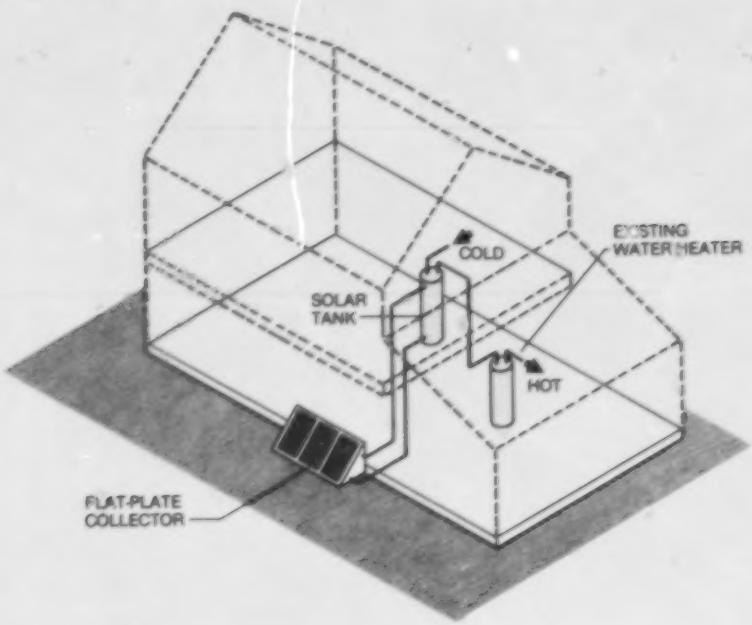


Figure 4-5: A flat-plate water heater installed in a house. Pipes between the collector and solar tank are small (1/2 inch or 3/4 inch diameter) so they are easy to conceal. The solar tank can be installed wherever convenient, but preferably close to the existing water heater. Note that this diagram has been simplified; refer to Figure 4-4 for full plumbing details.

Figure 4-6: A thermosiphon water heater. Warm water from the collector rises into the solar tank; cool water from the solar tank sinks into the collector. Thus a thermosiphon system circulates without aid of a pump. Note that the bottom of the tank must be 2 feet above the top of the collector to prevent reverse circulation at night.



Commercial water heater

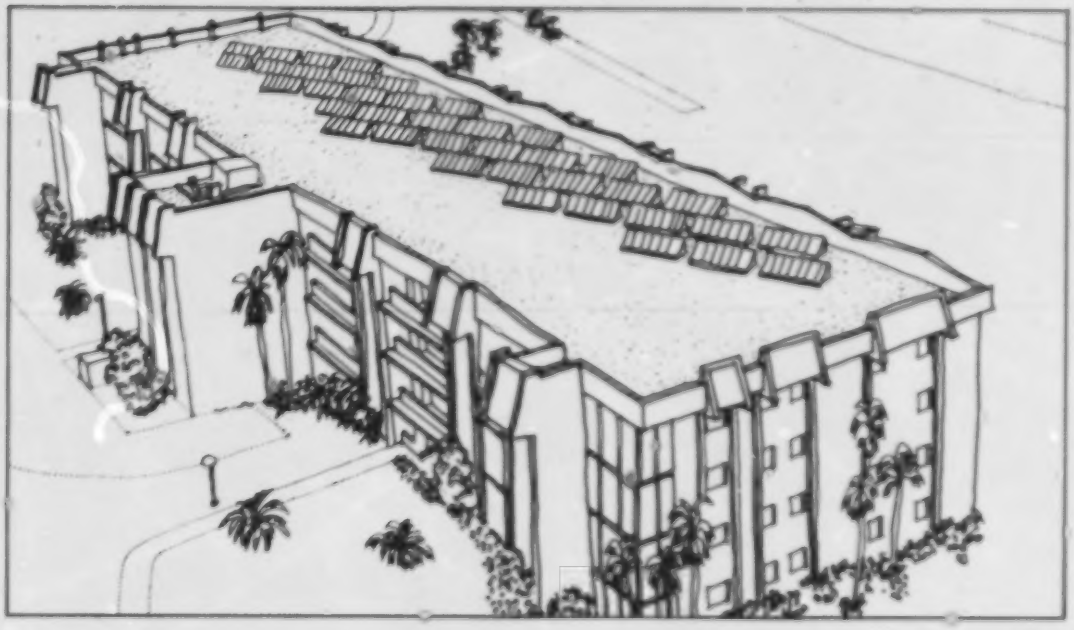
The pumped solar water heater previously described can be expanded to just about any size to supply large quantities of hot water for commercial use. Laundromats, laundries, restaurants, car washes, laboratories, hotels, apartment buildings, dormitories, and schools are examples of buildings in which large amounts of hot water are generally used.

Since many commercial buildings have flat roofs, these large solar water heaters frequently use several rows of free-standing flat-plate collectors, as shown in Figure 4-7. Except for its size, the plumbing arrangement of a large system is identical to that of the smaller water heater shown in Figure 4-4.

Certain characteristics of some commercial operations make it possible to install relatively inexpensive systems. Many businesses require hot water only during working hours. The solar storage tank can be relatively small in that case, since there is no need to save hot water for use in the evening. In other situations where a continuous flow of hot water is required, no storage tank is needed at all. Cold water is fed directly from the city mains through the collectors to the back-up heater.

Any business that uses hot water should consider converting to solar. Depending on the specific situation, large amounts of energy and money can be saved with this kind of installation.

Figure 4-7: Free-standing flat-plate collectors mounted on the roof of an apartment building.



The numerous solar energy systems capable of heating a house or building require large collection areas and storage capacity, so they're generally much bigger and more expensive than solar water heaters. We've included eight examples of solar space heating systems, both passive and active, to give you a sense of the different designs, costs, appearances, and operating modes. At the end of this section, we compare the performance of passive and active systems.

Windows and skylights

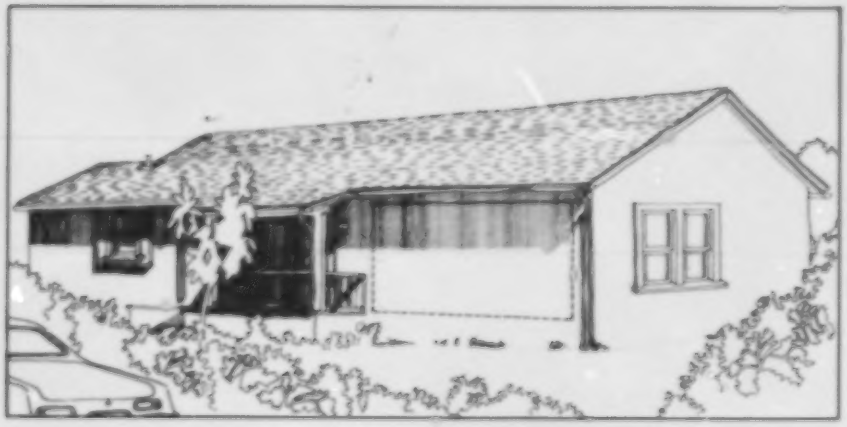
As discussed in Chapter 1, windows and skylights are the most basic – and very effective – solar collectors. If there's an available area on the south walls of your house, you can get a daytime heating boost simply by adding more window area, as shown in Figure 4-8. Skylights can also provide solar heat if the glazing is sloped and oriented toward the south – otherwise it won't "see" the sun, which is low in the sky during the winter. (An alternative is to use a reflector.) Before you start cutting holes in the walls or roof, however, check whether the affected rooms already overheat on sunny winter days. If they do, don't add more glass – you're already at the upper end of the comfort range. If the rooms overheat only during the summer, go ahead, but put up an overhang to keep out the high summer sun.

Installing windows is a common construction job that a skilled do-it-yourselfer or any competent carpenter can do. If the space next to the new glass area has a slab floor, you might consider putting in a sliding glass door (a double-glazed one), so the sunlight reaches as much of the slab as possible. Installing skylights is a little trickier. Be sure that the skylight glazing is well sealed, both to reduce heat loss and to prevent leaks. We recommend looking at *The Skylight Book* (Chapter 8, reference E-7) for guidance.

It is possible to store some of the solar energy windows and skylights admit if concrete or water is positioned so sunlight strikes it between 9 a.m. and 3 p.m. If your house has a dark-colored slab floor next to the potential south windows or under the potential skylight, the concrete will provide some storage. The total amount of heat that can be stored this way, however, would probably be quite small in comparison to the overall house heating requirements. It is possible to provide more storage by placing drums or tubes filled with water where the sun will shine on them during the midday hours. We will discuss these arrangements in the next section.

In addition to considering storage of solar energy, you should be concerned with reducing the heat loss back out through the expanded glass area. Since a single pane of glass (or any type of glazing) is a relatively poor insulator, the windows can lose more heat than they gain unless insulation is provided for nights and cloudy periods. Ordinary drapes and shades are often worthless in this respect. Drawing insulating curtains, putting up fitted insulated panels, or closing insulated shutters over the

Figure 4-8: The south wall of your house is the place to add additional windows. Many houses have south walls with few or no windows, since they were not designed to use the sun.



windows, however, can cut your heat loss substantially. See *Low-Cost, Energy-Efficient Shelter* (Chapter 8, reference A-7) and *The Solar Home Book* (reference B-5) for information on these conservation methods. Another option is to install double-glazed (insulating) windows. Probably the best measure for skylights is to install insulated shutters that can be pulled closed.

An important application of retrofit south-facing skylights is in commercial warehouses. The contents of the warehouse serve as storage for the solar energy that comes in during the day. This arrangement saves not only heating energy but also electrical power used for lighting.

Drum wall

The previous section made the point that additional south glass will not contribute substantially to house heating needs unless a means of storage is also available. Unfortunately, most Bay Area homes are not made of materials, such as concrete and stone, which store heat well. There are a number of ways to create storage, however, and that's what the next three sections are about.

One basic method for adding storage is to build a heavy *wall* behind the south-facing glass. Hammond's drum wall, discussed in Chapter 1, is a prime example of this approach. Sunlight coming through the south-facing windows shines directly on the metal, water-filled drums; the water absorbs the heat and re-radiates it to the house. The drums can be placed in the wall horizontally, as Hammond's are, or vertically. Lengths of 12 inch or larger diameter steel culvert, upended and welded to a water-tight base, can also be used as water containers for a storage wall.

However, you can't just start hauling in drums or culverts – most floors can't withstand their weight once they're filled with water. Have a structural engineer look at your floor if you are interested in building a drum wall. If your floor is not strong enough, you have at least two alternatives, both of which involve a fair amount of construction. One is to add a room with a large south-facing glass area and a well-reinforced slab-on-grade floor. This is what Hammond did. The other solution is to knock out a portion of the south wall of your house and build a concrete slab foundation just wide enough to accommodate the drums or culverts and the glazing. This option is shown in Figure 4-9.

In either case, be sure to put in glazing that extends down to the floor and as high as the drums or culverts. This is necessary because the containers must be exposed to direct sunlight to effectively collect and store solar energy. Any drums or portions of culverts below or above the glazing do not "see" the sun, and can only gain heat indirectly from the other drums or the air. A sliding glass door unit could be used, as that is a relatively inexpensive way to get a large, framed piece of glass. The fixed panel of the unit could accommodate about 9 barrels or several culverts without their encroaching on the doorway, or both panels could have barrels behind them.

As we saw in Chapter 1, drum walls can be used for cooling during the summer. If you live in an area with hot summer days, but relatively cool nights, this system can significantly reduce your air-conditioning bill.

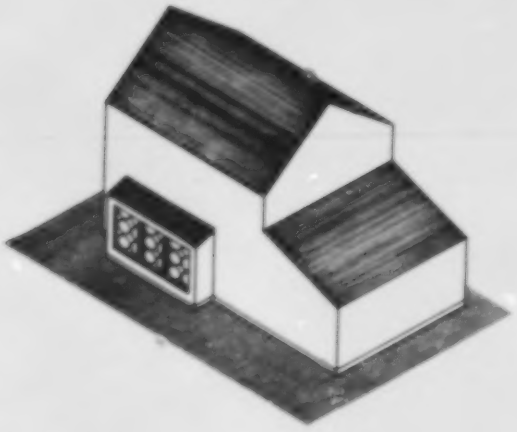


Figure 4-9: An example of a drum wall retrofit that did not involve a complete room addition. A small foundation was added to support the drums.

Tube wall

A tube wall is a version of the drum wall that requires less alteration to your house. As shown in Figure 4-10, a double-glazed row of 6 to 12 inch diameter water-filled tubes is installed over a blank area of your south wall. The tubes act as both collector and storage.

Heat is delivered to the house by blowing air past the back of the tubes with a fan. The warm tube surfaces heat the air. In simple systems, a thermostat-controlled fan blows warm air directly into the adjacent room. When the water in the tubes is not hot enough to provide the necessary heat, the existing heating system serves as a back-up.

A more elaborate arrangement is possible if you have a central forced air heating system. The return duct is rerouted through the tube wall. The tubes then preheat the air going from the house to the furnace. The furnace controls are modified so that the fan can operate separately from the burner. If the preheated air is warm enough to heat the house, the burner is not turned on. A second house thermostat, set one or two degrees lower than the one that controls the fan, turns on the burner if the tube wall air can't keep the house warm enough.

Trombe wall

A south wall heating system can also be built of thick masonry materials – grout-filled concrete block, brick, stone, or solid concrete. As with the drum wall, however, its weight requires an ongrade foundation. To use this system on a wood-frame house, you'd have to knock out a south wall or incorporate the system into a room addition with a southern exposure. The best-known example of such a system is the Trombe (rhymes more or less with "home") wall, named after the French engineer who developed it. The standard Trombe wall is a south-facing concrete wall, 8 to 12 inches thick, with a 4 to 6 inch air space between the wall and the glazing that covers it. The south-facing side of the wall has a roughened surface and is painted black. As you can see in Figure 4-11, there is also series of vents through the top and bottom of the wall, and windows can be in it as well.

There are several aspects to the system's operation. Most of the space heating is done by solar energy being absorbed by the exterior wall surface and slowly transferred through the wall into the house. How much heat can be collected and how long it can be stored depends on how thick the wall is. A one foot thick Trombe wall generally can store enough heat to last through a night and well into the next day.

Once a Trombe wall has exhausted its heat storage, however, it takes a while to warm up again. So the system also provides a way of getting heat into the house as soon as the sun comes up. Air between the wall and the glazed cover is heated by the sun and quickly begins flowing through the high vents into the house.

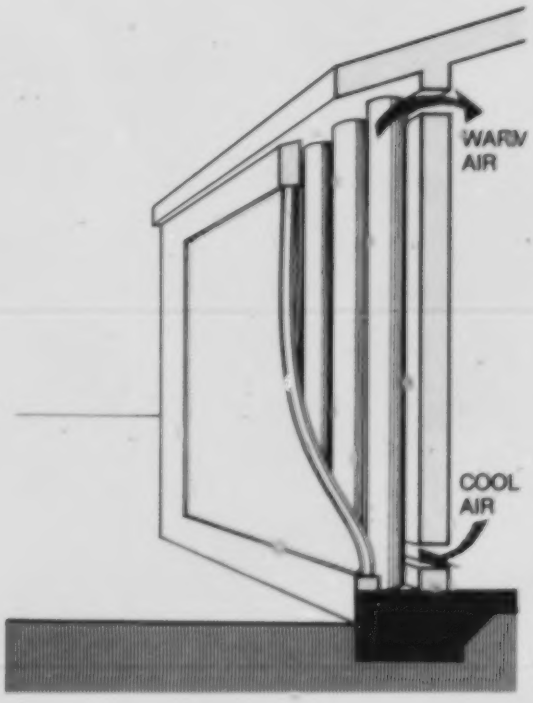


Figure 4-10: The tube wall. The double-glazed, black irrigation pipes or steel culverts absorb the sunshine and the water in them warms up. When heat is needed, air is blown behind the tubes and picks up heat from them. This system would provide more heat if it had shutters that are closed at night to prevent heat loss. In the Bay Area, though, the shutters cost more than the additional energy output is worth, so we recommend double glazing.

Cooler house air passes through the low vents into the air space and is heated again. This flow of air will cycle naturally without the aid of a fan. Windows in the south wall will also let sunlight directly into the house.

The mass of the Trombe wall can be used to store coolness, much as a drum wall can be. Build an overhang so the summer sun does not strike the concrete surface. Then use night breezes to cool the house and the storage wall for the next day.

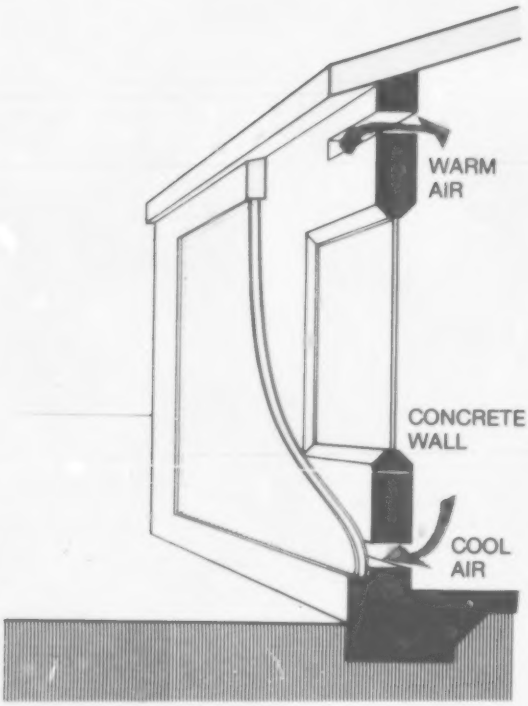


Figure 4-11: **The Trombe wall. The window allows some direct solar heating to supplement what flows through the wall and the hot air that rises into the living space through the top vents. Double glazing keeps heat losses low.**

Attached greenhouse

Greenhouses have been around for a long time (witness the flower-filled glass "conservatories" of 19th century Europe), but only recently have they been designed to be efficiently solar-heated. A well-designed solar greenhouse attached to a building's south wall can provide heating for the building in addition to keeping itself warm.

The basic design and operation of an attached solar greenhouse is relatively simple, as shown in Figure 4-13. The sun shines through the greenhouse glazing (one or more layers of glass, fiberglass, or plastic) and heats up the interior of the greenhouse. The more south-facing glass there is, the more solar energy can be collected.

The heat can be stored in numerous ways. A concrete slab floor will absorb the energy of the sunlight shining on it. Brick or dirt floors work well, too. So do water-filled 55-gallon drums or tubes lined up against the wall between the greenhouse and the building. The wall itself will store heat if it's built of masonry materials. How much storage there is and how effectively it's utilized are major determinants of how much solar heat is left over to be delivered to the house or building.

The easiest means of delivering heat to the building is simply to open windows or doors in the wall the greenhouse encloses, and let the heated air flow into the rooms. This natural circulation will be improved by cutting vents through the top and bottom of the common wall, so heated air can rise more easily into the house and cooled house air can sink through the low vents back into the greenhouse for reheating. A fan can be installed by one of the vents to increase circulation. The best way to deliver heat throughout the entire house or building, instead of mostly to the room(s) adjoining the greenhouse, is to direct the solar heated air into the existing forced-air heating system. However, sophisticated engineering is required for this set-up to perform well.

The cost of an attached solar greenhouse can vary tremendously, depending on the materials used, whether the unit is owner designed and built or contracted out, and whether it's assembled from a kit or build from scratch. A 250 square foot (floor area) greenhouse with fiberglass glazing and inexpensive storage can be owner built for under $1,000. Salvaging windows and wood for framing could lower that cost. On the other hand, a contractor-

built glass and redwood greenhouse with a slab floor could run as high as $20 per square foot of floor area.

An attached solar greenhouse has other benefits besides heating itself and part of the adjacent building. It can serve as a sun room, usable most of the year (with properly designed overhangs and storage, overheating can be minimized). It will use the heat otherwise lost through the house windows and wall area enclosed by it. If built around a house entrance, the greenhouse serves as a vestibule, keeping cold air from getting into the house when the door is opened and closed. The greenhouse will also provide a nice home for a breadbox water heater – the greenhouse acts as an extra glazing and will improve the water heater's performance.

If substantial plant growing is done in the greenhouse, your new sun room will be more visually attractive. In addition, plants will freshen the air in your house. This is especially important if your house is "tight" (now that you've weather-stripped it). Plants can even help you pay for the cost of the greenhouse. You can grow some of your own food and house plants. If you are ambitious, you can grow a cash crop such as flowers or vegetable starter seedlings. Some greenhouse owners without the time for or interest in gardening have even rented their greenhouses to neighbors with green thumbs. For complete information on attached solar greenhouses, see *The Food and Heat Producing Solar Greenhouse; Design, Construction, Operation* (Chapter 8 reference B-6).

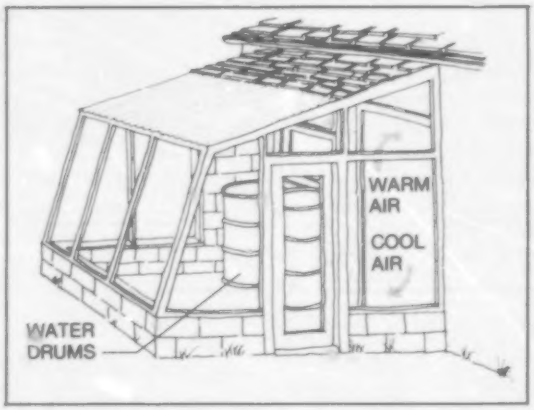


Figure 4-13: Solar greenhouses are often built over existing doors or windows. Hot air flows into the house when the door is open. The water drums are the heat storage in this greenhouse.

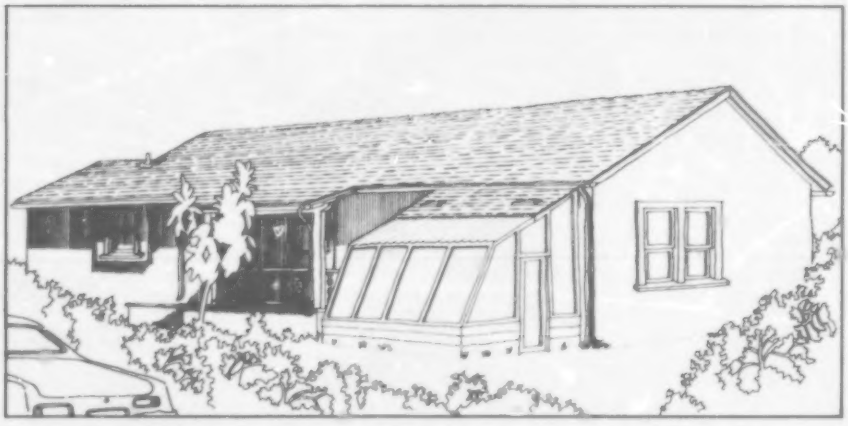


Figure 4-12: A house with a retrofit solar greenhouse.

No-storage air heaters

These simple heating systems operate by circulating air from the house or building through a flat-plate collector (located on the roof or against the south wall) and back into the building. Performance is limited because there is no storage—only daytime heating is possible.

These systems are well suited for commercial buildings, such as warehouses or factories. Many buildings of this sort need heat only during the daytime, so the lack of storage is not a problem. Figure 4-14 shows a large fan-powered version of this system. It is possible to use a fan-powered air heater without storage on a house as well. However, this may overheat the house on sunny days unless the collector area is held to a minimum.

Simple, thermosiphon air heaters called window box collectors make nice do-it-yourself projects. Figure 4-15 explains how they work. Window box collectors are installed below south-facing, ground-level windows, as shown in Figure 4-16. They contribute some daytime heating for the rooms to which they are connected. Window box collectors are unique in that they are portable—if you rent, you can take them with you when you move. See *Low-Cost Energy-Efficient Shelter* (Chapter 8, reference A-7) for a discussion of simple air heaters.

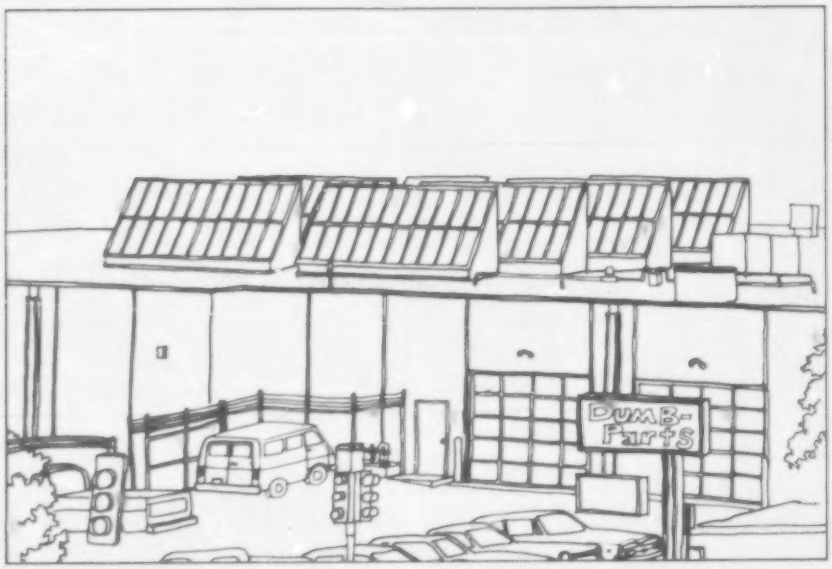


Figure 4-14: Air flat-plate collectors that deliver heat directly into a warehouse. This type of system is often a simple retrofit on flat-roofed buildings.

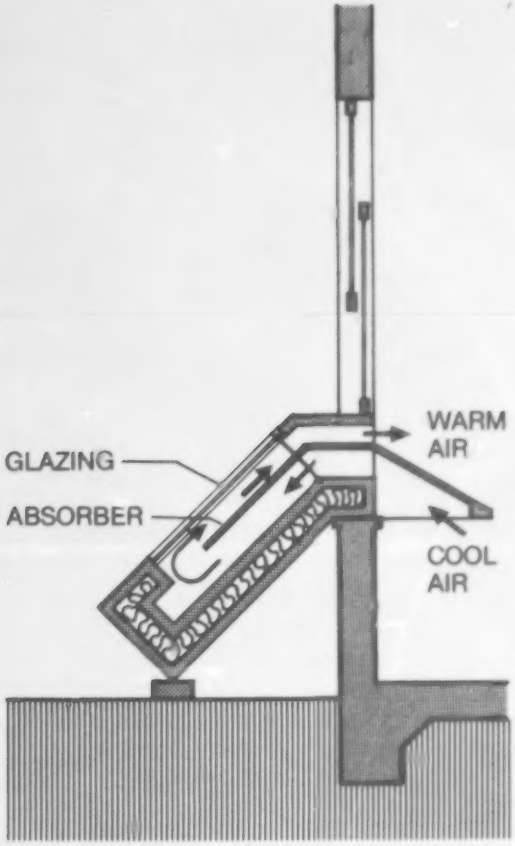


Figure 4-15: The window box collector is a simple thermosiphon air heater that is installed in an existing window. Air is heated by the black absorber and it rises into the room. This pulls new cool air into the collector. Because the air moves slowly, it does a poor job of picking up heat from the absorber. Window box collectors therefore produce fewer BTU's per square foot than fan-driven collectors. However, they are simple and inexpensive to build.

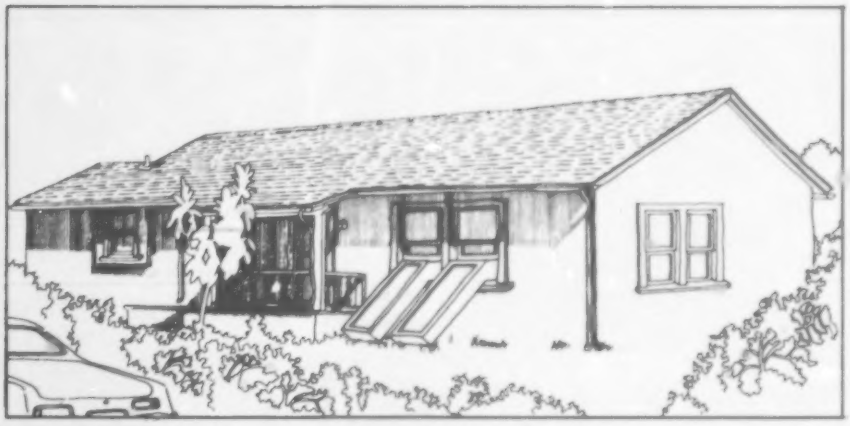


Figure 4-16: Window box collectors in place below south facing windows.

Flat-plate heating systems using water

Active solar heating systems using water-type flat-plate collectors fit well with existing central heating systems, either forced air or hot water (such as radiant floor slabs and baseboard convectors). If you do not have a central heating system, you have to install one in order to use this type of solar system. Unless you are planning to install central heating anyway, its added cost is a good argument for choosing one of the systems previously discussed.

An active system will require a large area of flat-plate collectors to do a significant portion of your space heating requirements. The collectors are usually mounted either flush or free-standing on a south-facing roof and cover much of the available area. The Heinemann house, discussed in Chapter 1, is an example of this kind of retrofit. It is shown in Figure 1-3. Another house using flat-plate collectors is shown in Figure 4-17.

A solar space heating system that uses water as the heat transfer fluid is essentially a large solar water heating system plus a delivery system for transferring heat from the storage tank into the house. Figure 4-18 shows such a system coupled with a radiant floor slab. Note the coil in the storage tank — this allows the system to provide hot tap water as well as heat for the house.

A water-type solar heating system can be hooked into a forced air heating system by installing a heating coil in the return duct, as shown in Figure 4-19. The coil is similar to an automobile radiator. Hot water from the solar tank is pumped through the coil, while air is blown through it by the furnace fan. The air leaves the coil hotter; the water returns to the solar tank cooler. As with the tube wall, the furnace controls are modified so the burner ignites only when solar heat cannot keep the house warm.

Whether a heating coil can be installed easily depends on the details of the existing heating system. Sometimes the duct layout requires expensive modifications before a coil can be added. In other cases, a more powerful fan may be required in the furnace. Have a heating contractor or solar consultant look over your forced-air system if you want advice on connecting into it.

Integrating with a hydronic system is a much simpler matter. A few plumbing connections are generally all that is required. Radiant floor slab systems operate by pumping warm water (80 to 110°F) through pipes in a concrete floor. The pipes warm the floor and the floor heats the house. Baseboard convector systems warm the house by pumping hot water (120 to 160°F) through finned pipes that run along the room perimeters. When a solar system is installed, solar heated water is pumped directly to the floor or baseboard pipes. Because high temperatures are harder to reach with a solar heating system, baseboard systems are not as well suited to retrofitting as radiant slabs.

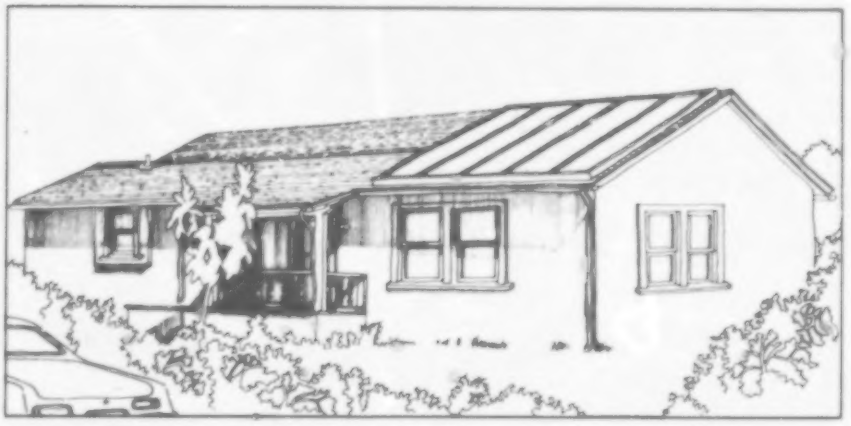


Figure 4-17: A house with about 200 square feet of flat-plate collectors mounted flush on a low-pitched roof.

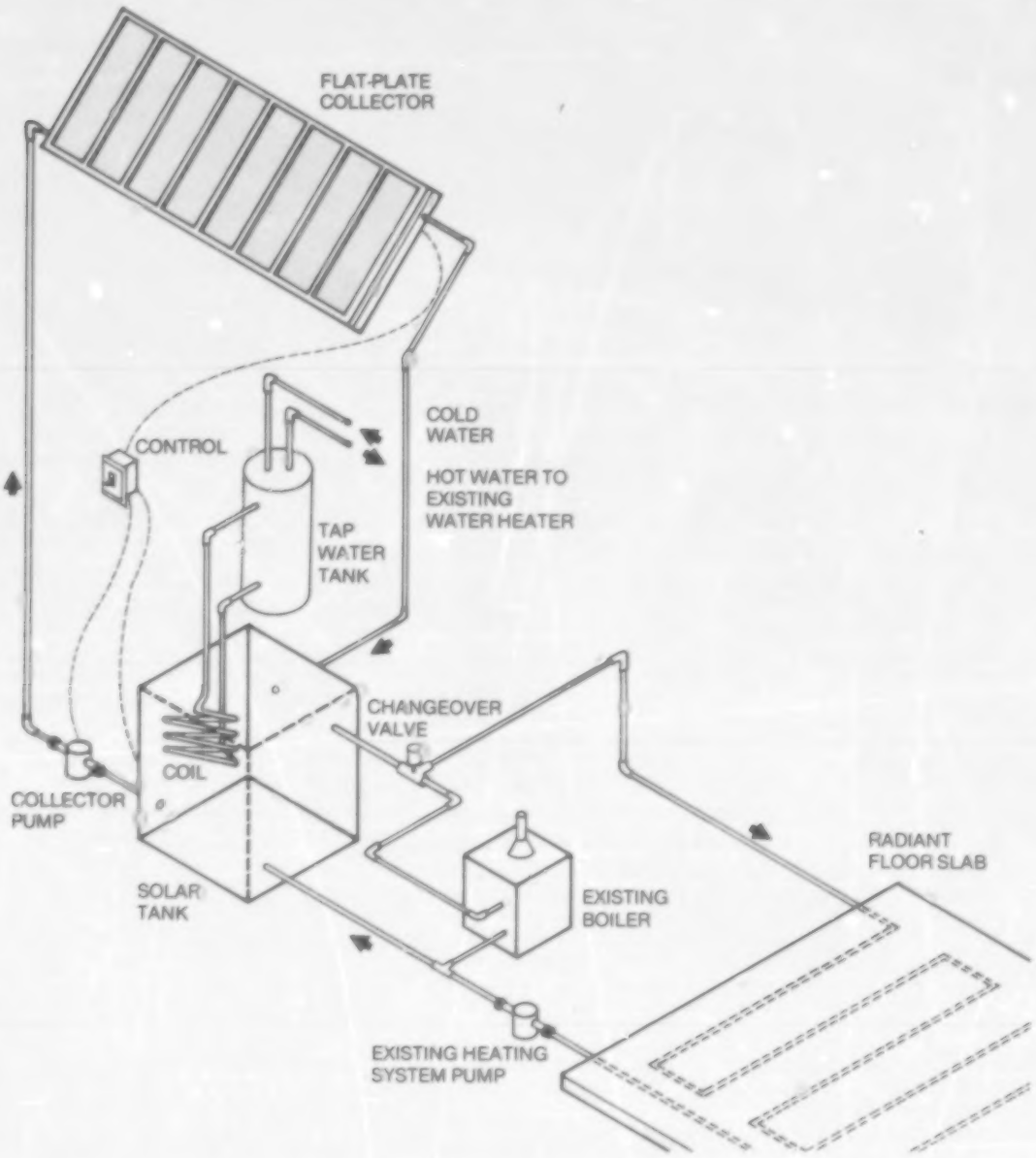


Figure 4-18: Schematic of a flat-plate heating system using water. The main circulation pipes are 1 inch or 1 1/4 inch in diameter. The control activates the collector pump as described in Figure 4-4. The coil in the storage tank heats tap water for household use with thermosiphon circulation to and from the tap water storage tank. The changeover valve causes the heating system water to be routed through the boiler when the solar storage tank does not contain water hot enough to heat the house. The automatic controls that cause the changeover valve to operate are not shown.

All water-type solar heating systems involve a large storage tank. Although its size depends on the size of the system, the tank typically has a capacity of about 1,000 gallons or 125 cubic feet (a cube 5 feet on a side). Such a tank weighs around 10,000 pounds, so a secure, ground-level location must be found for it. Here are some possibilities for tank installations:

- *Buried.* Burying the tank in the yard gets it completely out of the way; however, buried tanks are relatively expensive.
- *Garage or carport.* If you have a garage or carport with a slab floor, you can install the tank in a corner — the slab is usually strong enough to support its weight. Some local retrofits have used tall, narrow rectangular tanks that fit flat against a garage wall.
- *Outside shed.* You can build a small shed on the outside of your house, as shown in Figure 4-20. This works well, because the shed can often be unobtrusively located, yet still be convenient to the collectors and furnace. However, the shed adds to the system's cost.
- *Basement.* The few Bay Area houses with basements have an ideal location for a storage tank.

It is possible to connect several small tanks together to make a large capacity. This is sometimes handy in retrofit systems because it is possible to get small tanks (like 200 gallons) through a doorway. Keep this possibility in mind if you have restricted access to the place where you want to put your tank.

Trickle collectors can be used in water systems in place of tube and plate collectors. As we saw in Chapter 1, in trickle collectors the water runs down over the surface of the hot absorber plate and collects at the bottom in a gutter. Trickle collectors are inexpensive and therefore appealing as a do-it-yourself system. However, there are a number of problems with them. First, they require more maintenance than tube and plate systems; for instance, the holes that trickle the water can get plugged with mineral deposits. Second, trickle systems are not as efficient as tube and plate systems, so larger collection areas are required to provide the same output. Third, they can be noisy — the trickling water sounds like a continual rain on a metal roof and this has bothered some owners. Fourth, trickle systems are more prone to leaks than tube and plate systems, since there is a lot of loose water running around. So, if you want to build and maintain an inexpensive

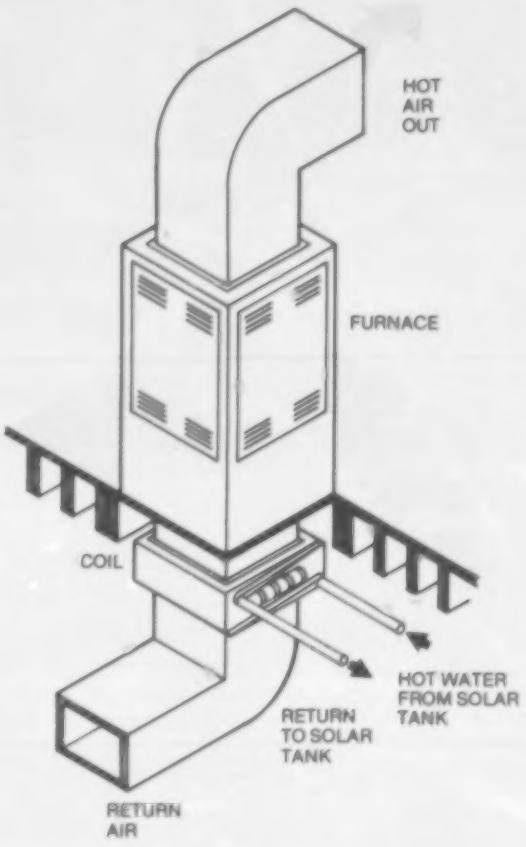


Figure 4-19: A heating coil in the return air duct of a forced air heating system. The furnace burner operates less because the air coming into the furnace is preheated by the coil.

system, consider a trickle system. For most people, however, the extra cost of a tube and plate system is worth it.

Any active system is complex and should be carefully designed. There are numerous ways active systems can either perform poorly or wear out quickly. If you design the system yourself, have your plans checked by an engineer or a solar consultant. It is not worth saving money on design fees and risking poor performance when you are going to put in a system worth thousands of dollars.

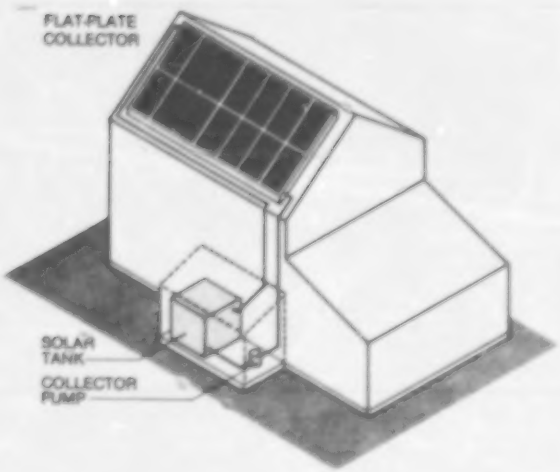


Figure 4-20: A retrofit installation in which the storage tank, pump, and related equipment are installed in a small shed added beside the house. The heating system equipment is not shown.

Flat-plate heating systems using air

If you have a central forced air heating system or are planning to install one, you can use an air-type solar heating system. Air systems have the same external appearance as water systems (see Figure 4-17), but internally they are very different, as shown in Figure 4-21. Air systems offer several advantages over water systems: they cannot freeze or boil and do not have to be absolutely leak tight.

Retrofitting with an air system presents the double problem of finding space for the rock bed and for the ducts, both of which are large. For this reason, air systems have not been used on many retrofit projects.

The rock bed required has about three times the volume of an equivalent water tank (about the size of a Volkswagen van). The large size is needed because rocks have a lower heat capacity than water, so a greater volume is required to store the same amount of heat. Rock beds are expensive to bury; generally people build an above ground bin out of wood or concrete to hold the rocks. Garages, carports, outside sheds, and basements are possible rock bed locations. See the discussion about storage tanks in the previous section for more information.

The two ducts that connect the collectors and the rock bed are typically about 12 by 12 inches each. If you're lucky, you have a closet or corner that you can (and are willing to) box in to provide a path for the ducts. Otherwise, you may have to run them up the outside of your house. In some cases, the appearance of external ducts would rule out an air system.

It is more difficult to integrate a water heater with an air system than with a water system. Usually a heating coil like the one discussed under water systems (see page 67) is used to pick up heat from air returning from the collectors. Alternatively, a completely separate flat-plate water heater can be installed.

Air systems are a bit more difficult to design than water systems and as much engineering skill is required. Again, get advice from someone with experience when designing your own system.

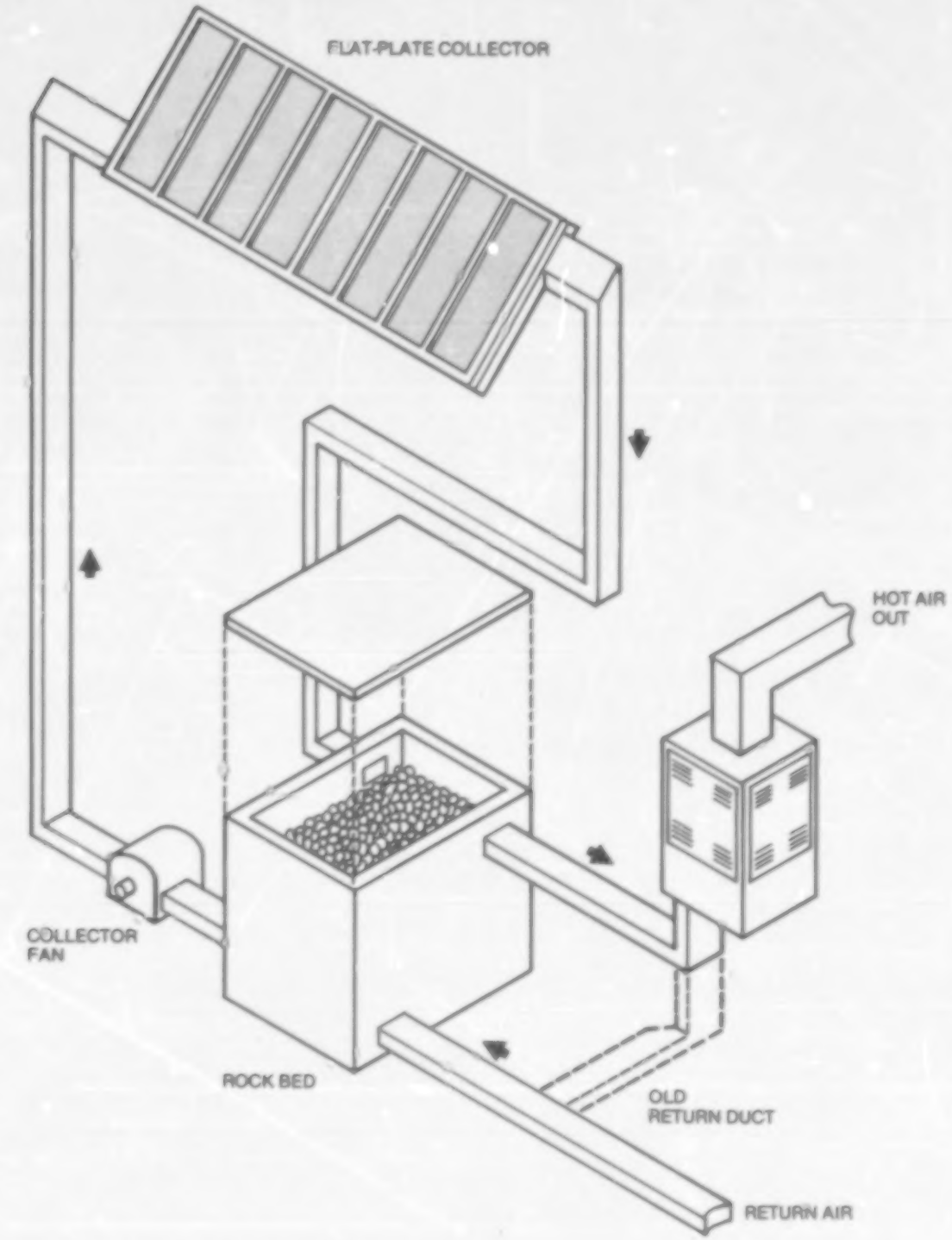


Figure 4-21: Schematic of an air flat-plate heating system. The system is inserted in the return duct before the furnace. Required dampers and controls are not shown.

Active vs. passive

You now have a good idea of the different types of systems available to you for retrofitting. A major choice you will have to make is between active and passive systems.

Active systems are similar to a central heating system in that they are controlled by a thermostat. When heat is required, the thermostat turns on the pump or fan in the system to provide it. You have complete control over the system – you can turn down the heat at night and then, with a touch of your finger, turn it up again in the morning.

On the other hand, passive systems follow the natural cycle of the day. The storage warms up during sunny hours and cools slowly when it's cold and at night. With a well-designed system, the temperature variations in the air are small, but most passive systems cannot give you a shot of instant heat whenever you want it. Some systems, like the Trombe wall and the greenhouse, start giving you heat immediately when the sun comes up. Others, like the drum wall, respond more slowly. Of course, the back-up heater would assure that you always have heat.

Many of the differences between passive and active systems come down to a matter of style. Some people value the quiet, even warmth that they can get with a passive system. Passive systems are also more reliable than active systems. In retrofit situations, though, they often require that an addition be made to the building. In many cases, active systems offer a simpler retrofit installation and give you better control. But the price you pay for this is the noise, maintenance problems, and energy consumption of the required pumps and fans.

If you own a pool, you know that it takes a lot of natural gas to heat it, often more than it takes to heat your house. With rising gas prices and talk of service cut-offs, you'd better look for an alternative. Solar energy is the best choice for lowering or replacing your present fuel use. Pools are perfectly suited to solar heating, as the existing circulation system already has all the necessary parts of a solar system except the collectors and controls. The pool itself serves as storage, and the pump and heater provide circulation and back-up. Figure 4-22 explains the plumbing of a pool system.

Swimming pool collectors are usually simple, unglazed absorbers mounted on any surface near the pool with a southern exposure. Since the collectors are used in the summer when the sun is high in the sky, the surface should have a slope between 10° and 30°. Although any orientation between southeast and west will work well, an orientation of 20° west of south is best. Figure 4-23 shows a typical installation.

Pool collectors are usually unglazed because they operate at pool water temperatures. During warm summer days, the air is often warmer than the pool, so glazing would actually reduce performance by preventing the absorber from picking up extra heat from the air. For pool heating during the early spring or late fall or in places with cool summer breezes, however, glazed metal collectors may be required.

Unglazed pool collectors are normally made of black rubber or plastic. They are available through many pool dealers. The different brands on the market vary widely in price, design, performance, and durability. We recommend that you shop carefully for pool collectors. Talk to people who have bought the brand you are considering before you buy it.

The size range for typical pool heating collection areas is between 50% and 100% of the pool surface area, depending on the local climate, the desired pool temperature, and the desired heating season. As a rule of thumb, this collector area will maintain comfortable swimming temperatures (75°F to 80°F) for a period about twice as long as the "natural" period when no pool heating is required. For instance, if your pool is comfortable in July and August without being heated, then a properly sized solar heater will provide satisfactory temperatures June through September without the use of the back-up heater. With a pool cover or lower swimming temperatures, a longer swimming

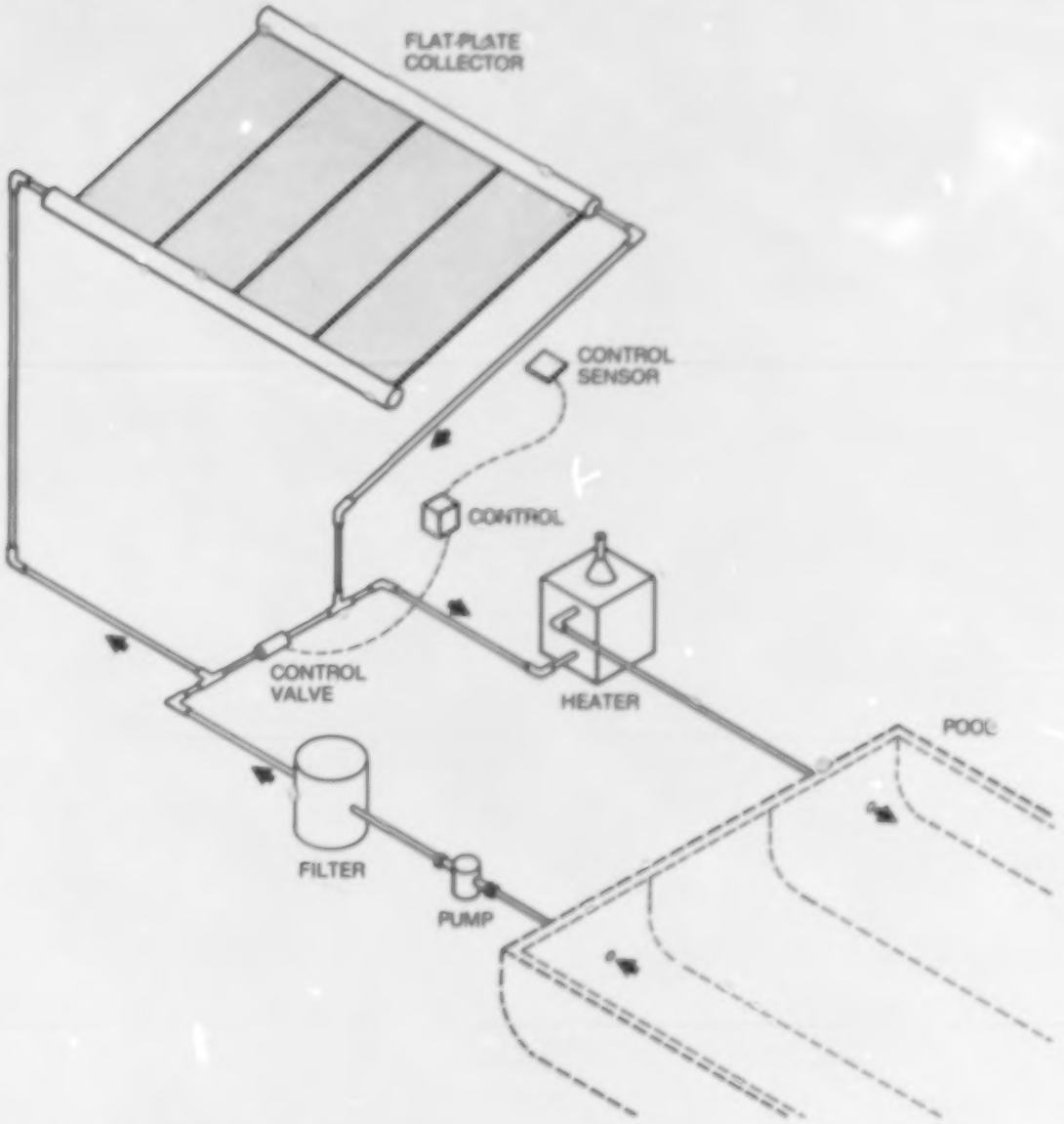


Figure 4-22: Schematic of a solar pool heating system. When the control sensor detects sufficient sunshine, the control valve routes the circulating water through the collector.

Figure 4-23: Collectors relaxing around the pool. In this case, some of the collectors face southeast while others face southwest. Because the sun is high in the sky during the summer, collector orientation is not critical for pool heating.

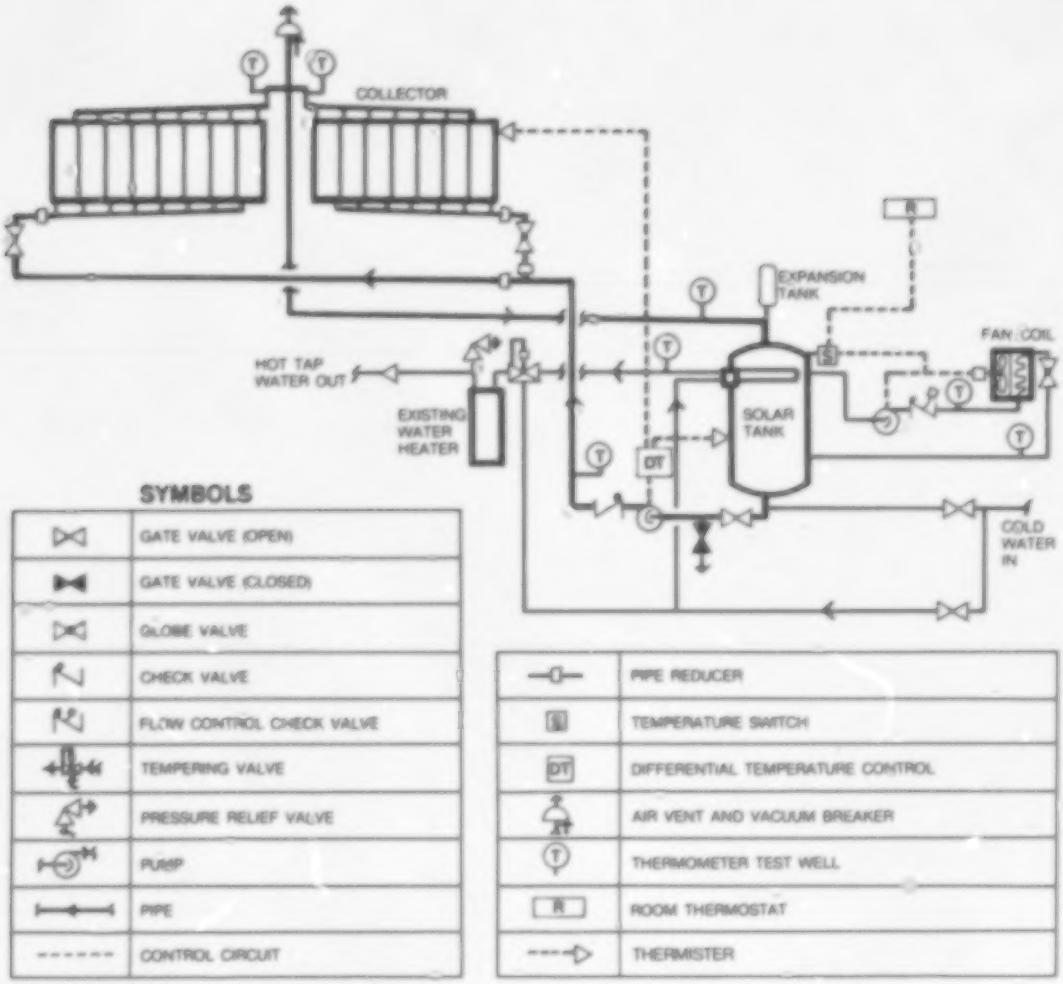


Figure 4-24: A complete engineering schematic for a flat-plate heating system using water.

season is possible. However, full year solar pool heating *cannot* be achieved in the Bay Area unless glazed collectors and a pool cover are used.

There are several ways to get a pool heating system installed. The most straightforward method is to hire a contractor who specializes in solar pool heating. Another approach is to do your own work, but still use commercial collectors. Finally, you could build the whole system yourself, including the collectors. See *How to Design and Build a Solar Swimming Pool Heater* (Chapter 8, reference E-5) for construction information.

Nuts and Bolts

We should point out once again that the schematic diagrams we show in this chapter are not blueprints. The active systems, especially, require many additional details in order to operate correctly. Each system has numerous variations that must be considered and used where warranted. An engineering schematic of an actual solar heating system is shown in Figure 4-24. Compare this to the diagram in Figure 4-18, and you'll see the level of detail that is required for a complete design. We repeat our advice to get competent help when designing a system and selecting equipment.

The following table gives you comparative information on all the systems in this chapter. Here's what the entries mean:

- *Typical size range:* This gives the "normal" size range of each system type. The collection areas are given in square feet, and the storage is given in gallons *per square foot of collection area.* For instance, a flat-plate solar water heater with a collection area of 50 square feet needs a storage tank of 75 to 150 gallons.
- *Typical collection area locations:* The most common locations for the collection area are marked with X's. Other locations are often possible – this is simply to give you an idea of the usual practice.
- *Performance:* The output per square foot of collection area is given. You'll get more specific performance information in Chapter 5.
- *Cooling possibilities:* Systems that offer some cooling possibilities are marked with X's. See the text for more complete information.
- *Design sophistication:* This rates the approximate difficulty of designing each system type. Systems rated "high" should have someone with solar engineering experience involved in the design.
- *Cost per sq. ft. of installed area:* This is the cost range of an *entire system* (collectors, storage, etc.) given in terms of the installed area. With these figures, you can estimate the approximate total cost for a system of a given size. Since prices vary and some components remain the same as a system gets larger (controls, for instance), these costs are for guidance only – the only accurate cost information is actual price quotes. The "Do-it-yourself" figures show prices for materials or components only; "Contractor installed" figures include labor costs.
- *Do-it-yourself:* This gives you an idea of the amount of effort and the skills required to build a system yourself. A rating of "small" means the project can be completed in a couple of weekends. "Large" projects involve several full-time weeks of work. One homeowner who built a solar heating system reported that he needed nearly every evening and every weekend for an entire summer to complete the job.
- *Things to watch out for:* This gives tips about specific problems that each system might have.

81

The System Comparison Table

Water heating systems

	Breadbox water heater	Flat-plate water heater	Commercial water heater
Typical size range			
Collection area	(see page 82)	20 - 100 sq. ft.	100 - 10,000 sq. ft.
Storage	40 - 200 gal. total	1.5 - 3 gal. per sq. ft.	.1 - 2 gal. per sq. ft.
Typical collection area locations			
Roof	(see page 55)	x	x
South wall		x	
Ground	x	x	
Performance	low	high	high
Cooling possibilities			
Design sophistication	low	medium	high
Cost per sq. ft. of installed area			
Do-it-yourself	$2 - $15	$4 - $20	$4 - $10
Contractor installed	$15 - $25	$20 - $35	$20 - $35
Do-it-yourself			
Size of project	small	small	large
Skills required			
Carpentry	x	x	x
Plumbing	x	x	x
Electrical		x (unless thermosiphon)	x
Other			
Things to watch for	• Tightly sealed glazing and box.	• Freeze protection • Bracing for thermosiphon tanks • Leaks	• Freeze protection • Roof leaks

Space heating systems

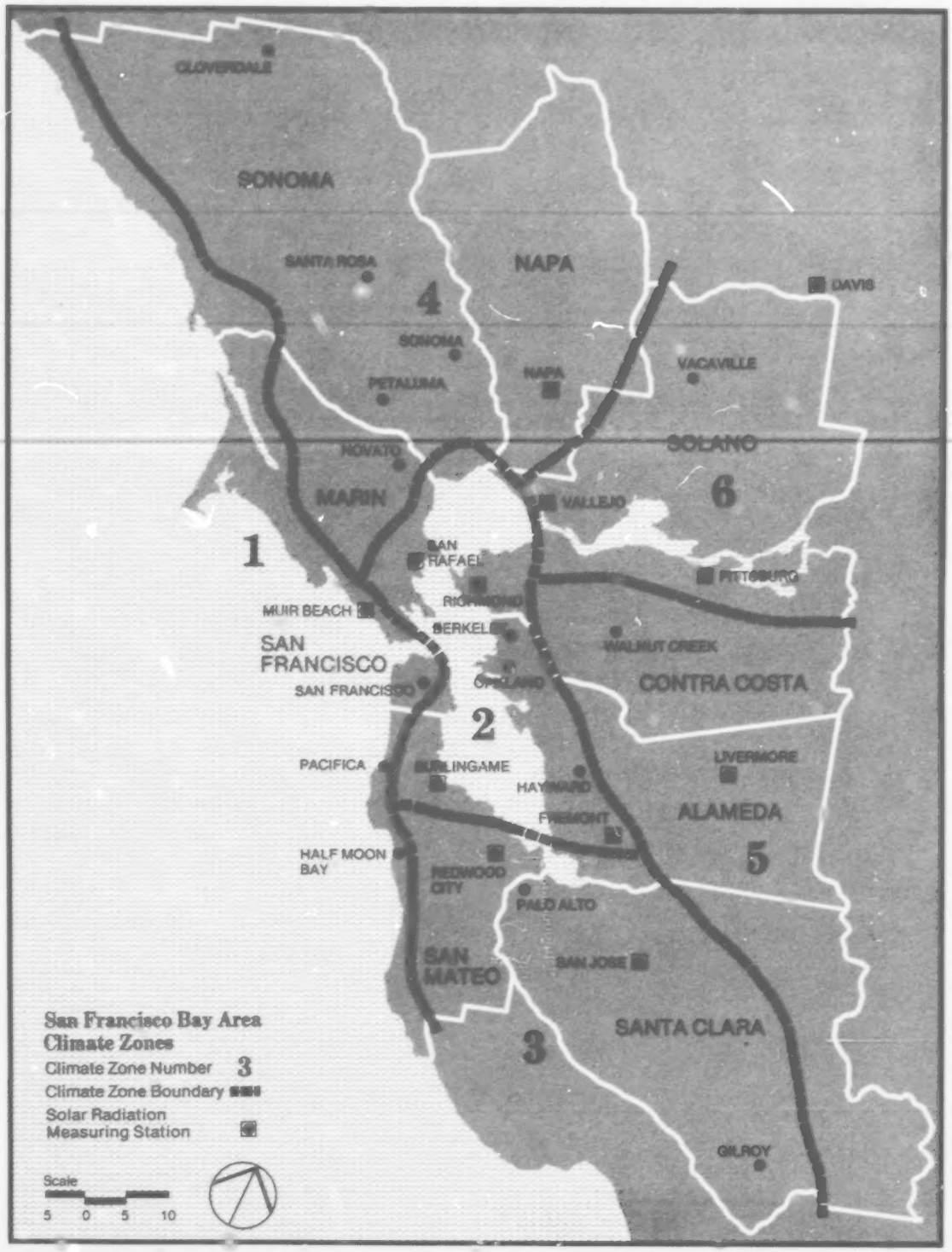
	Windows and skylights	Drum wall	Tube wall	Trombe wall
Typical size range				
Collection area	10 - 40 sq. ft.	20 - 400 sq. ft.	20 - 400 sq. ft.	20 - 400 sq. ft.
Storage	(see page 80)	4 - 20 gal. per sq. ft.	2 - 5 gal. per sq. ft.	80 - 150 lbs. concrete per sq. ft.
Typical collection area locations				
Roof	x			
South wall	x	x	x	x
Ground				
Performance	low	medium	medium	medium
Cooling possibilities		x		x
Design sophistication	low	low	medium	medium
Cost per sq. ft. of installed area				
Do-it-yourself	$3 - $5	$4 - $10	$5 - $10	$4 - $15
Contractor installed	$10	$10 - $20	$10 - $20	$12 - $25
Do-it-yourself				
Size of project	small	medium large	medium	medium large
Skills required				
Carpentry	x	x	x	x
Plumbing				
Electrical				
Other				masonry
Things to watch for	• Leak proofing skylights	• Support of weight • Earthquake bracing	• Support of weight • Earthquake bracing	• Support of weight • Earthquake bracing

Space heating systems

	Attached greenhouse	No storage air heater (with fan)	No storage air heater (without fan)	Flat-plate heating system using water (tube and plate)
Typical size range				
Collection area	50 - 400 sq. ft. of south glazing	100 - 1,000 sq. ft.	15 - 40 sq. ft. per heater	100 - 400 sq. ft.
Storage	2 - 3 gal. per sq. ft. of south glazing	none	none	1½ - 3 gal. per sq. ft.
Typical collection area locations				
Roof		x		x
South wall	x	x	x	x
Ground		x	x	x
Performance	low-medium	low-medium	very low	high
Cooling possibilities				
Design sophistication	low	medium	low	high
Cost per sq. ft. of installed area				
Do-it-yourself	$2 - $10	$3 - $15	$3 - $6	$6 - $20
Contractor installed	$10 - $20	$12 - $20		$15 - $30
Do-it-yourself				
Size of project	medium	medium-large	small	large
Skills required				
Carpentry	x	x	x	x
Plumbing				x
Electrical		x		x
Other				
Things to watch for	• Leak proofing connection to house		• Weather stripping of connection to window	• Freeze protection • Leaks

Space heating systems — Swimming pool heating

	Flat-plate heating system using water (trickle)	Flat-plate heating system using air	
Typical size range			
Collection area	100 - 500 sq. ft.	100 - 500 sq. ft.	50% - 100% of pool area (pool)
Storage	1 - 4 gal. per sq. ft.	50 - 100 lbs. rock per sq. ft.	
Typical collection area locations			
Roof	x	x	x
South wall	x	x	
Ground	x	x	x
Performance	medium	high	high
Cooling possibilities		x	
Design sophistication	medium-high	high	low
Cost per sq. ft. of installed area			
Do-it-yourself	$3 - $10	$4 - $20	$1 - $4
Contractor installed	$15 - $30	$15 - $30	$3 - $6
Do-it-yourself			
Size of project	large	large	small
Skills required			
Carpentry	x	x	
Plumbing	x		
Electrical	x	x	x
Other		sheet metal	
Things to watch for	(see page 69)	• Air leaks • Proper air distribution through collectors	


CLOVERDALE
SONOMA
SANTA ROSA
NAPA
4
DAVIS
SONOMA
VACAVILLE
PETALUMA
NAPA
SOLANO
NOVATO
6
MARIN
VALLEJO
1
SAN RAFAEL
PITTSBURG
MUIR BEACH
BERKELEY
WALNUT CREEK
SAN FRANCISCO
CONTRA COSTA
SAN FRANCISCO
2
PACIFICA
LIVERMORE
BURLINGAME
HAYWARD
ALAMEDA
FREMONT
5
HALF MOON BAY
REDWOOD CITY
PALO ALTO
SAN MATEO
SAN JOSE
SANTA CLARA
3
GILROY
San Francisco Bay Area
Climate Zones
Climate Zone Number 3
Climate Zone Boundary
Solar Radiation
Measuring Station
Scale
5 0 5 10

5: Estimating Performance

By now you probably have several types of systems in mind for possible retrofitting on your home or building. Two things remain to be considered about these systems – their performance and their cost – before you can make a final choice. This chapter is about performance; Chapter 6 deals with cost.

The performance (yearly heat output) of a solar energy system depends on four factors:

- The type of system
- The size of the system (particularly the size of the collection area)
- The amount of sunshine striking the collection area on a month-by-month basis
- The amount of heat required on a month-by-month basis

The Performance Charts in this chapter take all of these factors into account and allow you to estimate the performance of each system you are considering. The Charts were derived using a computer program that calculates the performance of solar systems operating under typical conditions.

There are several types of errors that could cause the Performance Charts to give incorrect predictions of system performance. First, there could be errors in our computer program. Second, the climate data we used could be inaccurate. In fact, as discussed in Appendix 1, after the Performance Charts were prepared, some of the sunshine data used have been found to be 5% to 20% incorrect. Third, the charts are strictly accurate only for systems identical to the ones we modeled, as discussed under "Representative Systems" on page 80. So, while the charts give good quick estimates of system performance, they are not reliably accurate. If you want an accurate performance estimate, consult an engineer with extensive solar experience. Appendix 1 on page 121 discusses the accuracy of the Performance Charts in more detail.

Climate zones

The amount of available sunshine and the amount of heat required for space heating depend on where you live (although your heating needs also depend on other things, such as how well your house is insulated – see Chapter 2, page 33). There are large differences in fog patterns, cloud cover, and temperature between regions of the Bay Area. For example, it can be 55°F and foggy in San Francisco, while it is 90°F and sunny inland at Walnut Creek.

To take these variations into account, we've divided the Bay Area into the six Climate Zones shown in Figure 5-1. As you will see later in the chapter, there is a set of Performance Charts for each zone. The zones were determined using the computer program mentioned above to compare the performance of solar heating systems in different places throughout the Bay Area. Locations with about the same solar performance were grouped together into one zone.

Two of the main variables that go into the computer program are *available sunshine* and *degree days*. Let's look at these in more detail to get an understanding of how the Climate Zones differ from one another.

- *Available sunshine.* Winter days are short, so there is less sunshine during the winter than during the summer. Weather conditions such as San Francisco's summer fog and inland winter tule fog also affect the amount of available sunshine in this region. The overall pattern for the Bay Area is that coastal areas receive more sunshine in the winter than inland areas do. In the summer, the inland areas are better off. If you study the sunshine data in Appendix 2, you'll see this pattern.
- *Degree days.* The amount of energy required to heat a conventionally built house in a particular location can be estimated from the number of degree days observed there. Early research and experience showed that a typical house needs no heat on days when the average outdoor temperature is 65°F or higher. Each degree that the daily average outdoor temperature falls below 65°F counts as one degree day. A day with an average outdoor temperature of 60°F, therefore, has five degree days. The weather bureau keeps records of the total number of degree days per month for many locations. The total for a particular location is proportional to the amount of space heating energy required there.

Appendix 2 on page 124 lists average monthly degree days for Bay Area locations. If you study the pattern of those numbers, you'll see that coastal locations, such as Half Moon Bay, have substantial numbers of degree days in the summer because of the cool sea breezes and fog. Some inland places – Antioch, for example – have no degree days during summer months. This means that no heat is required in Antioch during those months, and a solar space heating system would sit idle even though there is plenty of available sunshine. On the other hand, a similar system in Half Moon Bay would be used all year. If all other factors are equal, solar space heating is more practical in places with full year heating requirements, since there the solar equipment is always in use.

The amount of energy required for water heating is not dependent on degree days, but rather on the quantity and temperature of hot water used.

As a result of the variations in the amount of available sunshine and the number of degree days, solar space heating systems deliver more usable energy per square foot per year in coastal areas than they do inland. Solar water heaters have higher performance inland, since they operate all year and can take advantage of the strong summer sun in those areas. The Performance Charts will give you more exact estimates.

One more note on climate matters. This discussion and the Performance Charts are based on an *average* of the weather data recorded over the last 5 to 30 years. Any single year can be substantially different from the average. Your year-to-year performance will probably be higher or lower than what is predicted by the Performance Charts, but over 5 or 10 years it should average out to the performance estimated here.

Representative systems

In preparing the Performance Charts, we made specific engineering assumptions about each type of system. Since a particular system may differ in one or more details from our assumed system, the Performance Charts will not necessarily give accurate results in your specific case. For instance, our curves assume that collectors are single-glazed. If you are considering using double-glazed collectors, the Charts will indicate a lower % Solar than your system should provide.

The Representative System Table on page 82 and the following discussion present the details of how we modeled each system. This material is technical, but we advise you to look it over before using the Charts. It is especially important that you understand our assumptions if you are trying to use the Charts for a system that is "just a little different" from the one we discuss. The information in Chapters 1 and 2, as well as in this chapter, will help you estimate whether the output of your system will be higher or lower than the estimates provided by the curves. See Appendix 1 on page 121 and *ERDA's Pacific Regional Solar Heating Handbook* (reference B-13 in Chapter 8) for further information.

Some of the systems described in Chapter 4 do not have curves on the Performance Charts and therefore do not have representative systems. There is so much variation among windows, for instance, that it is impossible to predict how much solar heat they will trap. There are no curves for swimming pools, either; in most cases the rule-of-thumb sizing method discussed under "Swimming Pool Heating" on page 72 in Chapter 4 is adequate.

Table 5-1 shows the correspondence between the systems described in Chapter 4 and the Performance Chart curves. Refer to it before looking at the Representative System Table. You will also need to use Table 5-1 to select the correct curve for estimating performance of a system.

Table 5-1

Performance Chart Curve Selection

For this system type:	*Use the curve marked:*
Breadbox water heater	BREADBOX
Flat-plate water heater	FLAT-PLATE
Commercial water heater	FLAT-PLATE
Windows and skylights	—
Drum wall	WALL STORAGE
Tube wall	WALL STORAGE
Trombe wall	WALL STORAGE
Attached greenhouse	—
No-storage air heaters with fan	NO STORAGE
No-storage air heaters without fan	—
Flat-plate heating systems	
Tube and plate water or air	STANDARD
Trickle	TRICKLE
Flat-plate heating systems with water heater	
Tube and plate water or air	STANDARD + HW
Trickle	TRICKLE + HW
Swimming pool heating	—

The Representative System Table covers the following system parameters:

- Number of glazings: The number of ordinary window glass covers assumed to be on the collector. Transmission at normal incidence was assumed to be .86 for 1 glazing and .77 for 2 glazings. A dirt and shade factor of .95 was applied to these transmission values.
- Heat removal efficiency: The proportion of the solar energy absorbed by the collector plate that is then removed by the water moving through the collector. Well designed collectors have heat removal efficiencies of about .9.
- Collector loss coefficient: The insulating value of the collector glazing, insulation, and box. Heat losses from the collector depend on the collector temperature and slope, so the losses are written as equations. In those equations, T_{abs} indicates the average absorber temperature.
- Storage: The amount of water storage per square foot of collection area.
- Storage insulation R value: The amount of insulation around the storage tank. The tank is assumed to be outdoors.
- Downpoint: The storage temperature below which a heating system cannot deliver any heat.
- Heat transfer rate: The rate of heat transfer than can be achieved for each degree that the storage is above the down-point. This applies to heating systems only.

Other assumptions not described in the Representative System Table are:

- Plate absorptivity: .95; plate emissivity: .95 (flat black paint).
- For water heating systems, a hot water delivery temperature of 130°F was assumed.

  The following water use schedule was also assumed:

Time of day	Percent of daily use
8 a.m.	30
12 noon	20
3 p.m.	20
7 p.m.	10
10 p.m.	20

- Flat-plate heating systems using air were not explicitly modeled. However, it is generally agreed that overall performance of air systems is equivalent to that of water systems. A representative air system would have a heat removal efficiency of .67 and storage of 71 pounds of rocks per square foot of collection area.

Representative System Table

System	Number of Glazings	Heat Removal Efficiency	Collector Loss Coefficient (BTU per hr. per sq. ft. per °F)	Storage (gal. per sq. ft.)	Storage Insulation R-value	Downpoint (°F)	Heat Transfer Rate (BTU per hr. per °F)
Breadbox*	2	.7	$(1.06 + .0032\ T_{abs}) \cdot (1 - .0012\ [\text{slope} - 30°])$	4.4	R-15	—	—
Flat-Plate	1	.9	$(.49 + .0022\ T_{abs}) \cdot (1 - .0012\ [\text{slope} - 30°])$	1.8	R-19	—	—
Wall Storage	2	.95	0	3.6	R-1.67	70°	6 per sq. ft.
No Storage	1	.7	see Flat-Plate	10,000 BTU in building	—	—	—
Standard	1	.9	see Flat-Plate	2	R-30	80°	120
Trickle	1	.88	$1.94 + .0032\ T_{abs}$	2	R-30	80°	120

*Note: To account for the reflectors, the breadbox water heater was assumed to have an absorber area twice as large as the vertical cross section of the tank.

Using the Performance Charts

A Sample Performance Chart is shown in Figure 5-2. The curves on the charts relate the *Collector Load Ratio* (CLR) to the % *Solar* for each system type. If you know the CLR, you can use the appropriate curve to find the % Solar for a particular system, and vice versa. Let's take these terms one at a time.

- CLR: This is the ratio of the effective size of the collection area, in square feet, to the annual energy demand, in therms. That is,

  CLR =
  Effective Area ÷ Annual Energy Demand

  We use this ratio because it is the *relationship* between the size of the solar system and the size of the energy demand, not their actual sizes, that counts. For instance, if a system with a 100 square foot collection area meets a certain portion of a 300 therm annual energy demand, then a system with a 200 square foot collection area will provide the same portion of a 600 therm demand. Also, note that although everything is stated in terms of the size of the collection area, we are actually talking about the system size, including storage. As we discussed in the previous section of this chapter ("Representative Systems"), we have assumed certain amounts of storage per square foot of collection area for each system type.

- %*Solar*. The % Solar is the portion of the Annual Energy Demand that can be met by the solar heating system. It is difficult and expensive for a solar system to provide 100% of the heat required. Usually some fraction, ranging from perhaps 30% to 70%, is provided.

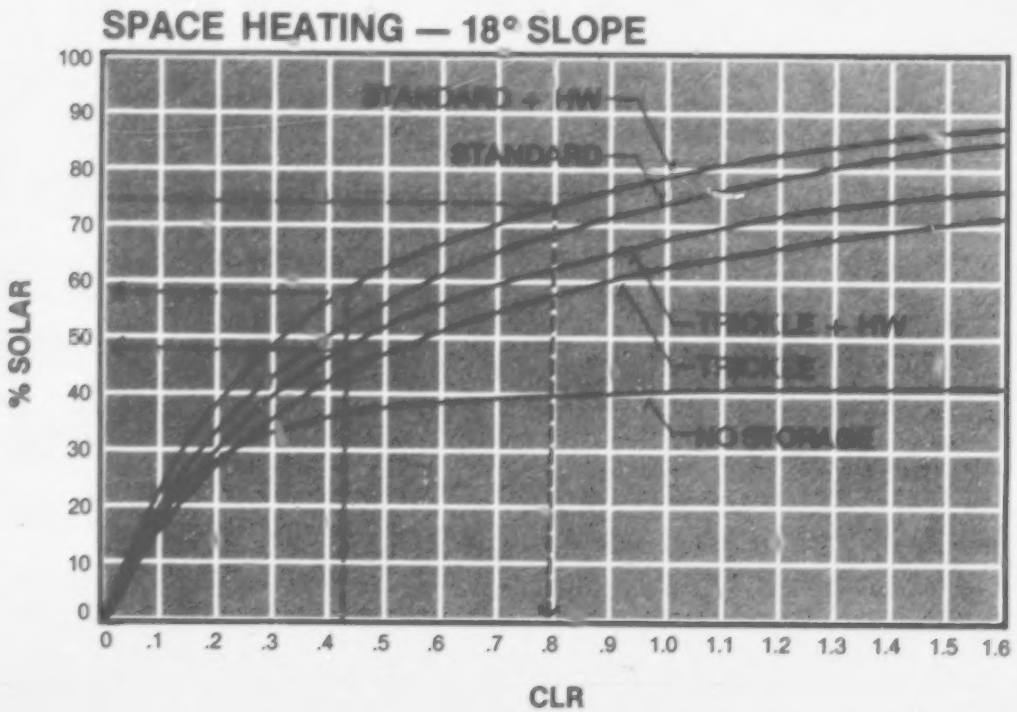


Figure 5-2: Example Performance Chart. For a CLR of .43, the STANDARD + HW system is 59% Solar, while the TRICKLE + HW system is 49% Solar. Using the Chart the other way, to get 75% Solar with the STANDARD + HW system, a CLR of .8 is required.

How to fill out Worksheet 8

You are now prepared to do some actual calculations. Refer to the Sample Worksheet 8 as necessary for guidance. Run through one complete calculation to learn how to use the worksheet. Then try as many combinations of different system sizes and types as you need to get an idea of how each system would perform in your situation.

- Climate Zone: *Find your Climate Zone number on the map in Figure 5-1.* If you live near a border between zones, you'll have to use your judgment about the local climate. Compare the weather in your location to that in places in the possible zones and choose the zone that is most like your situation. *Enter the Climate Zone number in the space provided on Worksheet 8.*
- Column A: *Enter the location and slope of the surface being considered from Lines 1 and 3 of Worksheet 7.*
- Column B: *Enter the name of the Performance Chart for your application and surface slope.* Take a look at the charts for your Climate Zone. The charts begin on page 87. There are four charts for each zone: one for water heating systems and three for space heating and combined space and water heating systems. Select the chart which fits your application and collection area slope.
- Column C: *Enter the name of the curve (from Table 5-1) you will use on the chart.* Note that some of the curve names appear on more than one chart. When you use the Performance Charts, always check that you are using the correct zone, chart, and curve.
- Column D: *Enter the Effective Area (in square feet) of the collection area from Line 11 of Worksheet 7.*
- *Skip Column E for the moment.*
- Column F: *Enter the Annual Energy Demand (in therms) that you want the solar system to supply.* For water heating, use the figure on Line 4 of Worksheet 6. For space heating, use Line 8 of Worksheet 6. For combined water and space heating with a single system, *add* the values from Lines 4 and 8 of Worksheet 6. If you plan to use different systems for water heating and space heating, you must make a separate calculation on Worksheet 8 for each. For instance, if you intend to install a flat-plate water heater and a drum wall, their performances must be calculated separately.
- *Skip Columns G to I for the moment.*
- Column J: *Enter the Orientation/Frame Factor from Line 10 of Worksheet 7 for the surface being considered.*

At this point, you can use the Performance Charts to go from a CLR to a % Solar, or vice versa, as discussed above.

Start with the CLR if you know the collection area and want to know the output of a system that size. For example, suppose you have an Effective Area on your garage roof of 100 square feet and you want to know what % Solar you would get if you covered all of it with a flat-plate water heater.

Start with the % Solar if you want to know what size the Effective Area would have to be to give you a particular output. For example, suppose you have a 600 square foot Effective Area and want to install a water heater. Since that area is much too large for a water heater, the thing to do is start with the % Solar you'd like, say 70%, and work backwards to find the Effective Area required to provide it.

Starting with a CLR

In this case, you work from left to right. You might want to make your first estimate using the entire Effective Area.

- Column E: *Enter the area you wish to try.* This Trial Area cannot be larger than the Effective Area in Column D.
- Column G: *Divide Column E by Column F to get the CLR.*
- Column H: *Turn to the appropriate Performance Chart and find the % Solar, as described in Figure 5-2.*

If the % Solar is larger than you want, run through the same procedure again, this time using a smaller Trial Area in Column E.

Starting with a % Solar

In this case, work from right to left.

- Column H: *Enter the % Solar you want to achieve.*
- Column G: *Find the CLR from the Performance Chart, as described in Figure 5-2, and enter it in Column G.*
- Column E: *Multiply the CLR (Column G) times the Annual Energy Demand (Column F) to get the area required to provide that output. Enter it in Column E.*

Sample Worksheet 8

Worksheet 8:
Performance Estimating

Climate zone: 7

A. Surface Location and Slope	B. Chart	C. Curve	D. Effective Area (sq. ft.)	E. Trial Area (sq. ft.)	F. Annual Energy Demand (therms)	G. CLR	H. % Solar	I. Annual Energy Saving (therms)	J. Orientation/ Frame Factor	K. Installed Area (sq. ft.)
Roof 19°	Water Heating	Flat-plate	142	142	118	1.2	89%	105	85	
				60	118	.51	77%	91	85	70
Wall 90°	Space Heating ~~90°~~	Wall Storage	48	~~0.5~~ 225	342	.66	50%			
			48	48	342	.14	14%	48	85	56
Roof 19°	Space Heating ~~19°~~	Structural + HW	142	142	460	.31	50%	230	85	167

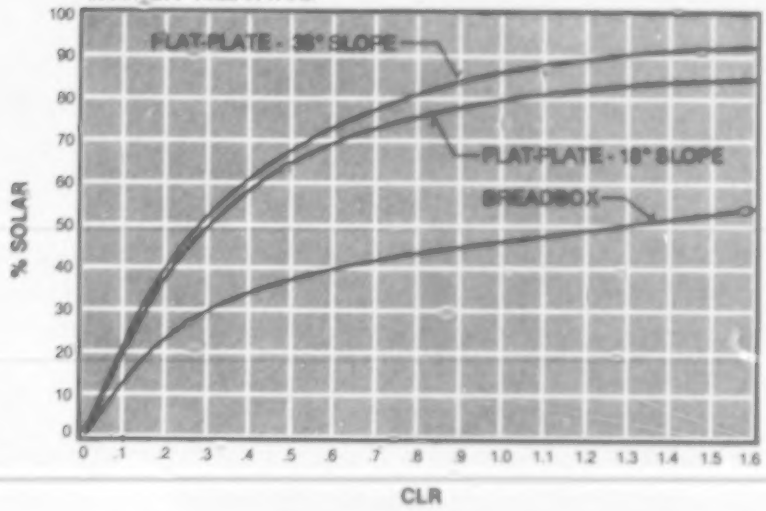
If this area is smaller than the Effective Area, then the Trial Area is a feasible size. If it is larger, you should try a smaller % Solar or a higher performance system.

To finish your calculation:

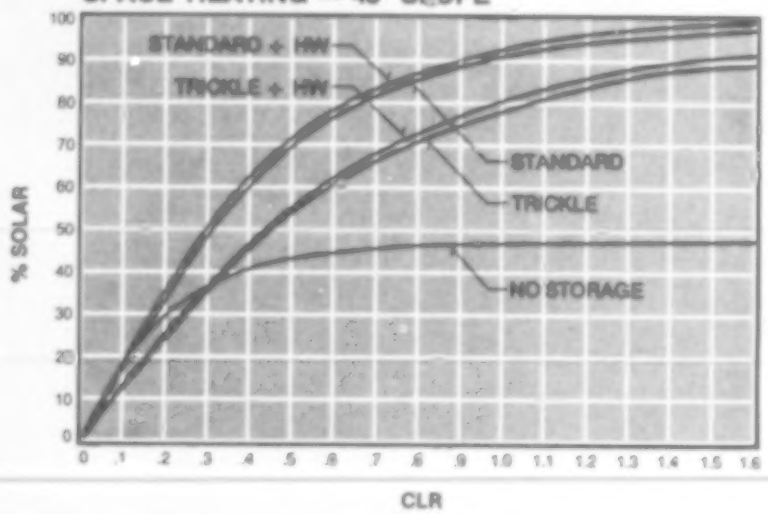
- Column I: *Multiply the decimal equivalent (59% = .59) of the % Solar (Column H) times the amount in Column F to get the Annual Energy Saving.* This is the amount of energy that the solar system will provide for you in an average year.
- Column K: In Chapter 6, you will need to know the overall Installed Area of your system, including frames, in order to estimate its cost. *Divide Column E by the Orientation/Frame Factor in Column J. Enter the result in Column K.*

When you have estimated performance for all systems you are interested in, you are ready to go on to Chapter 6 to consider the costs and savings you can expect from each.

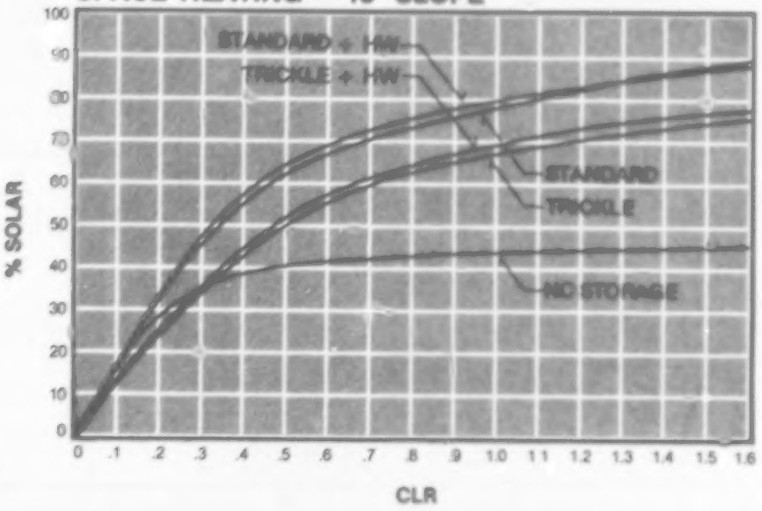
WATER HEATING



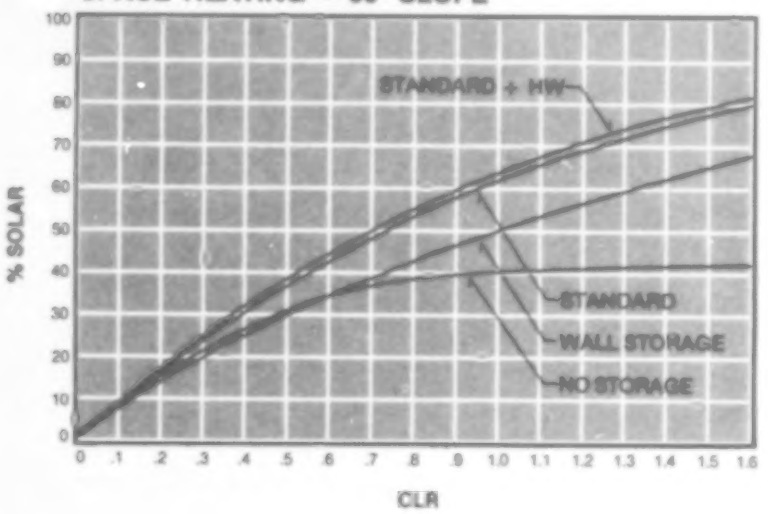
SPACE HEATING — 48° SLOPE

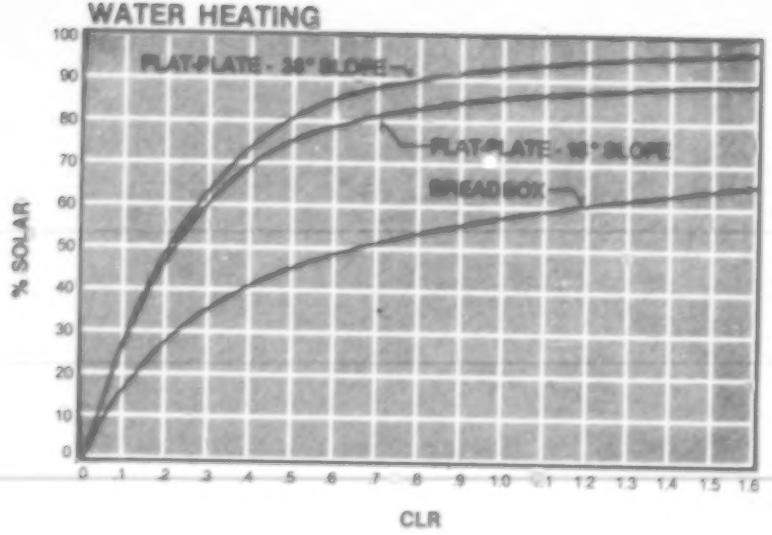


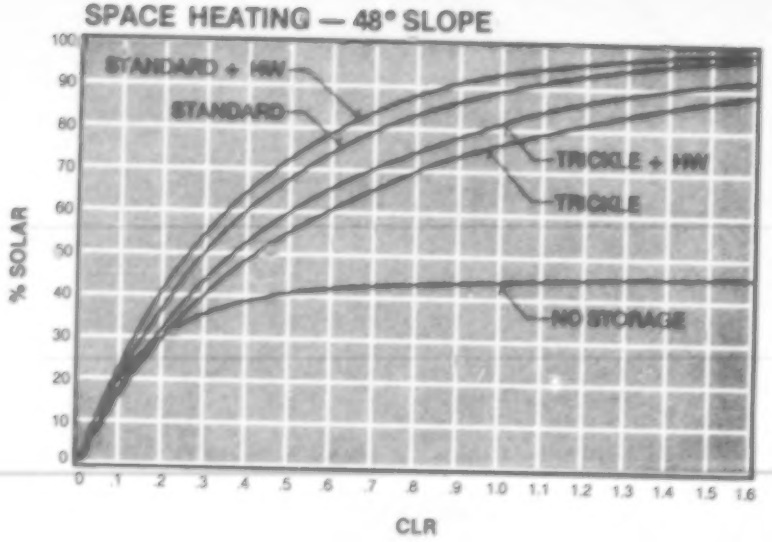
SPACE HEATING — 18° SLOPE

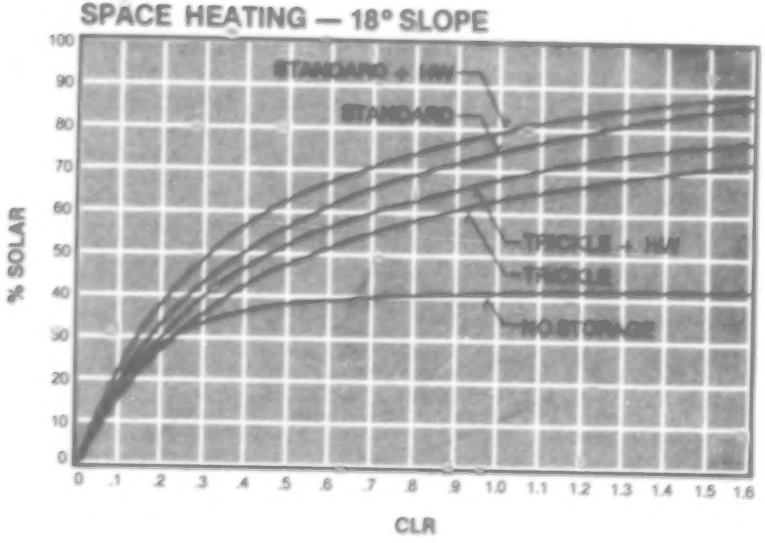


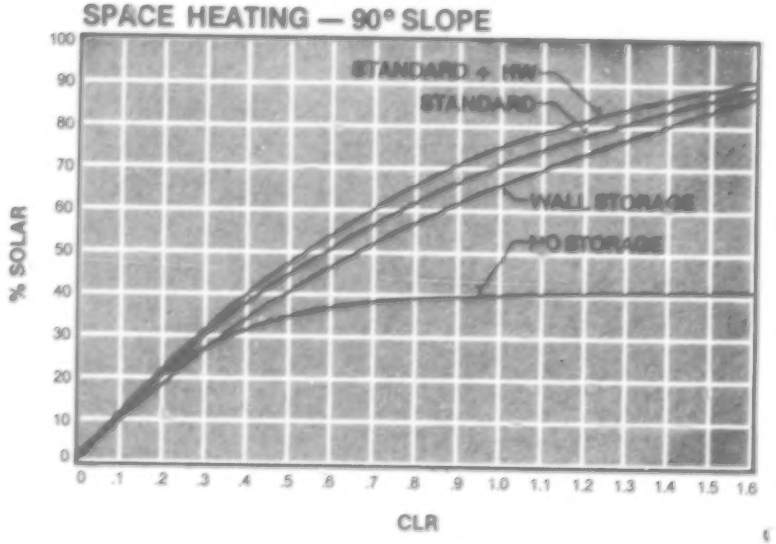
SPACE HEATING — 90° SLOPE



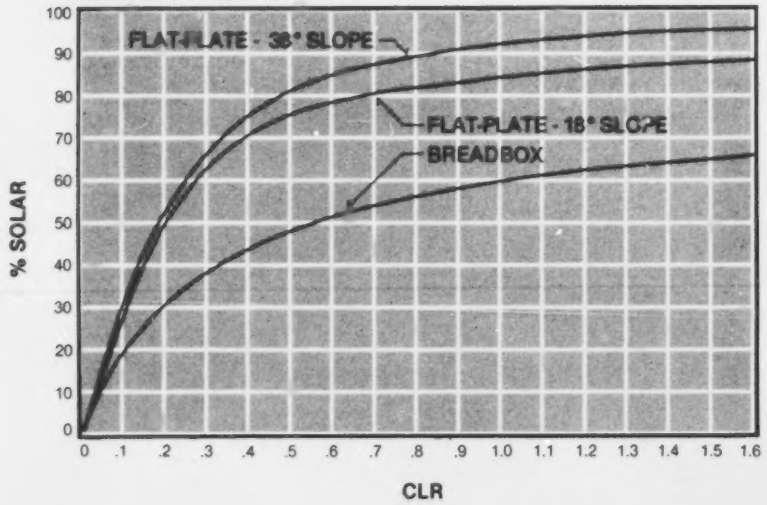

WATER HEATING
% SOLAR
CLR
FLAT-PLATE - 48° SLOPE
FLAT-PLATE - 18° SLOPE
BREAD BOX


SPACE HEATING — 48° SLOPE
% SOLAR
CLR
STANDARD + HW
STANDARD
TRICKLE + HW
TRICKLE
NO STORAGE


SPACE HEATING — 18° SLOPE
% SOLAR
CLR
STANDARD + HW
STANDARD
TRICKLE + HW
TRICKLE
NO STORAGE


SPACE HEATING — 90° SLOPE
% SOLAR
CLR
STANDARD + HW
STANDARD
WALL STORAGE
NO STORAGE

WATER HEATING



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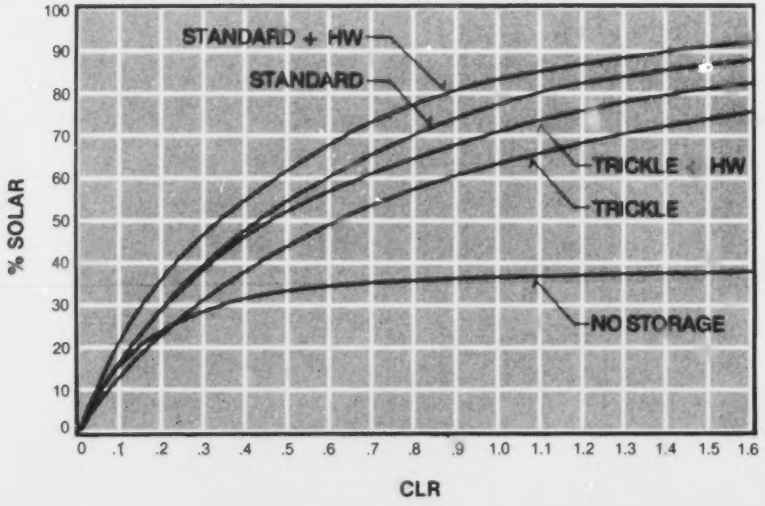

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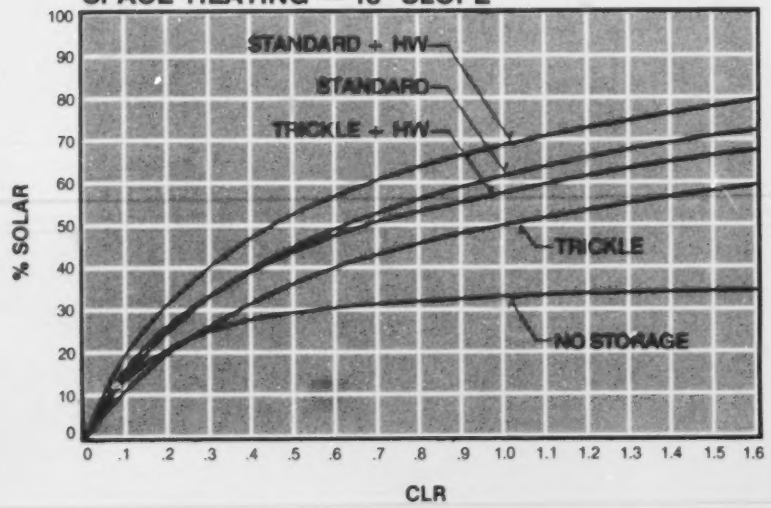

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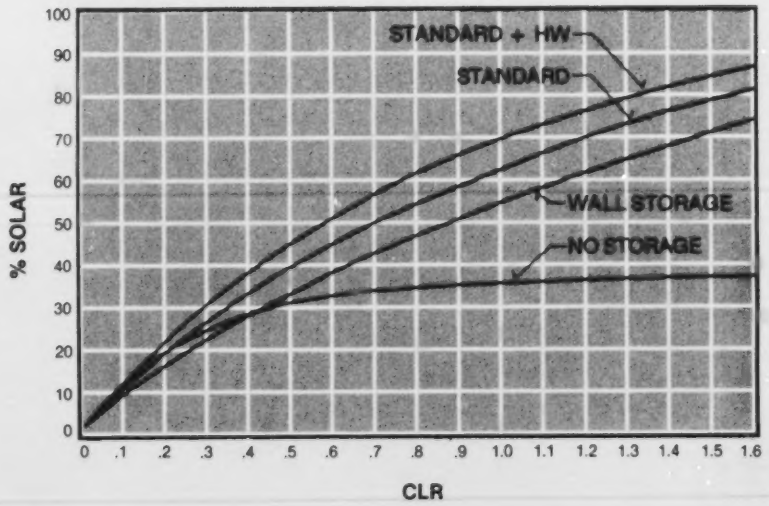
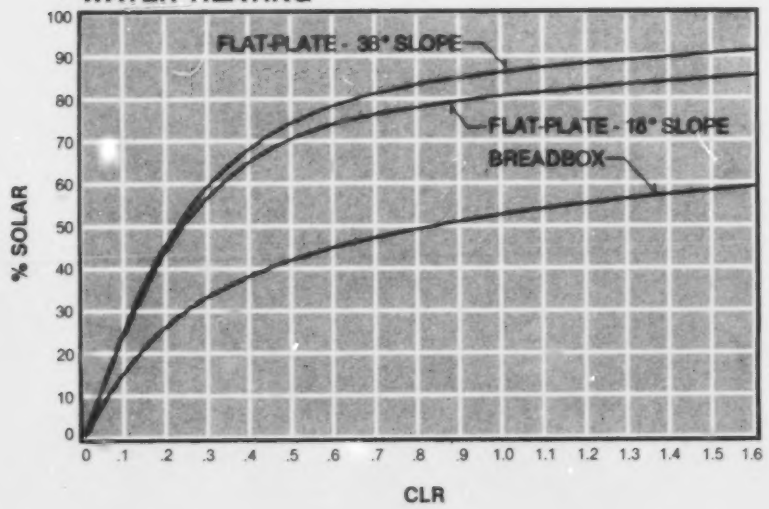


97

93

WATER HEATING



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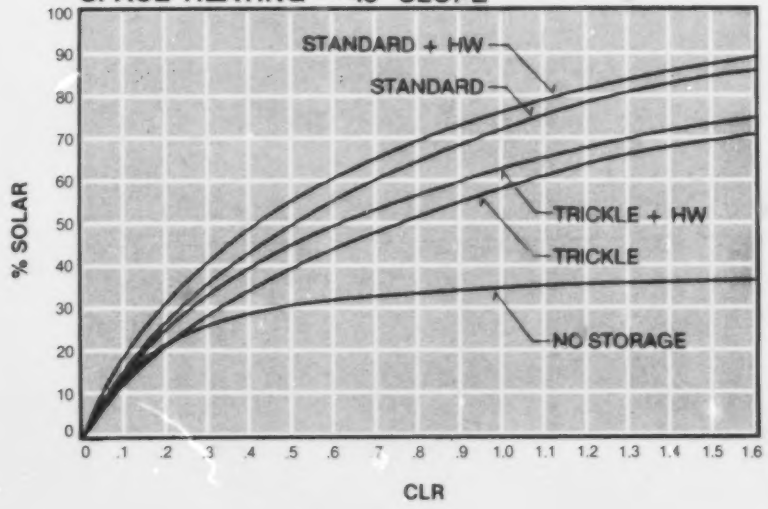
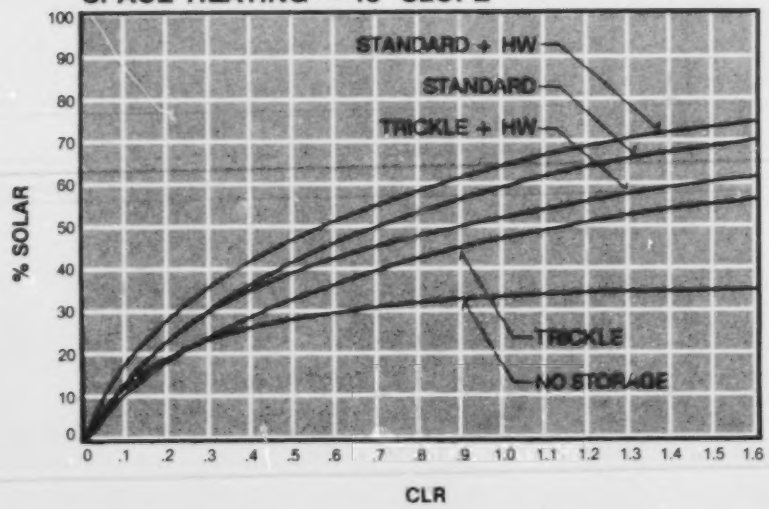
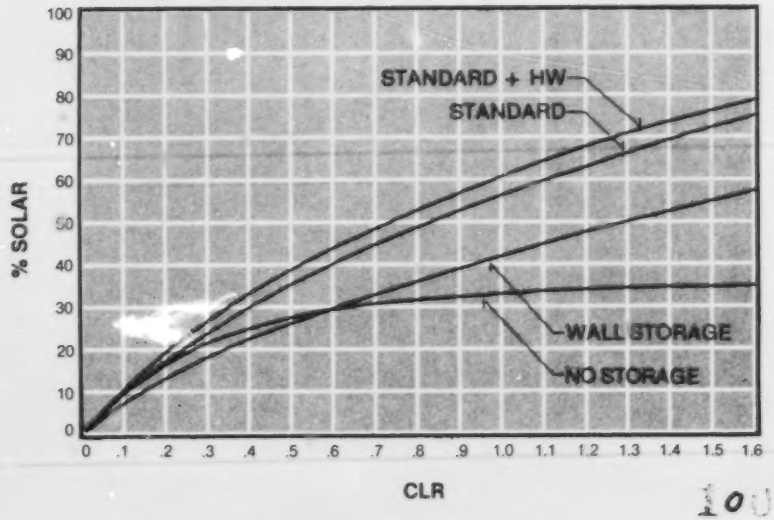


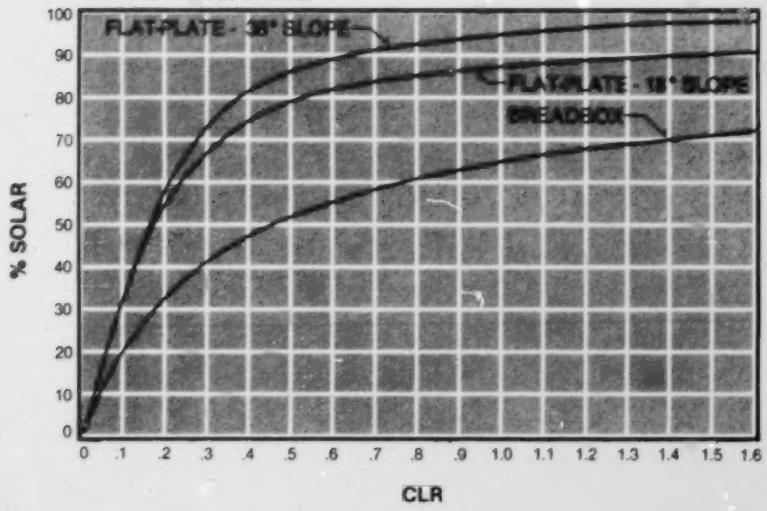
SPACE HEATING — 18° SLOPE



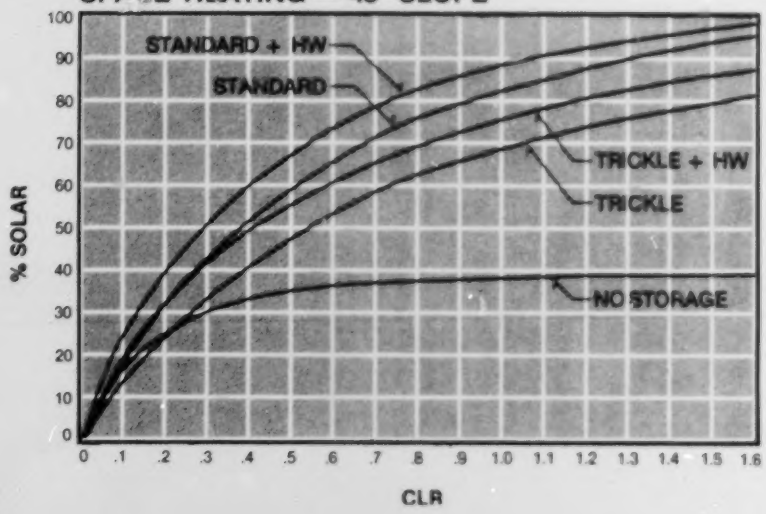
SPACE HEATING — 90° SLOPE



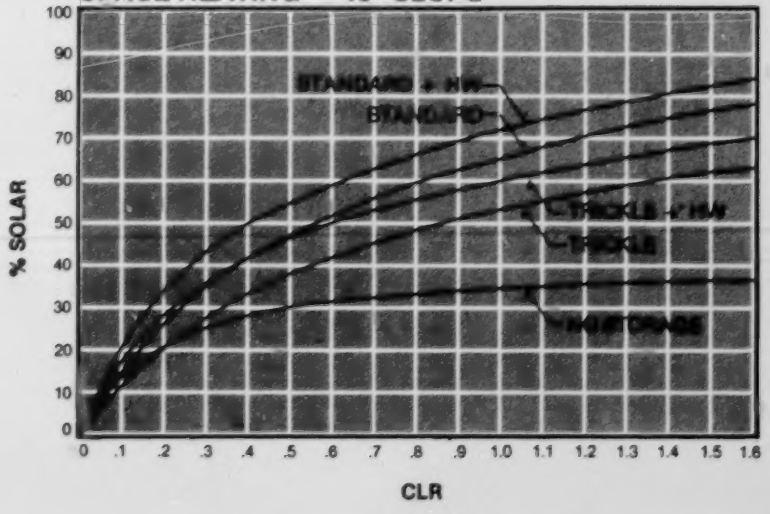
WATER HEATING



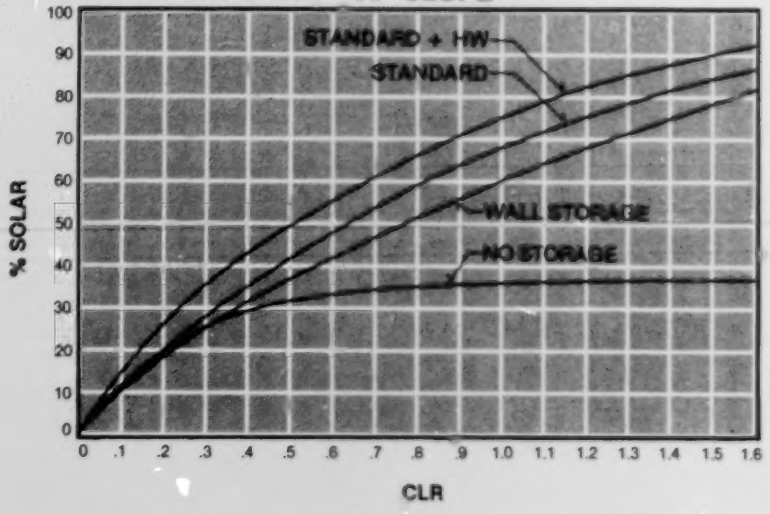
SPACE HEATING — 48° SLOPE



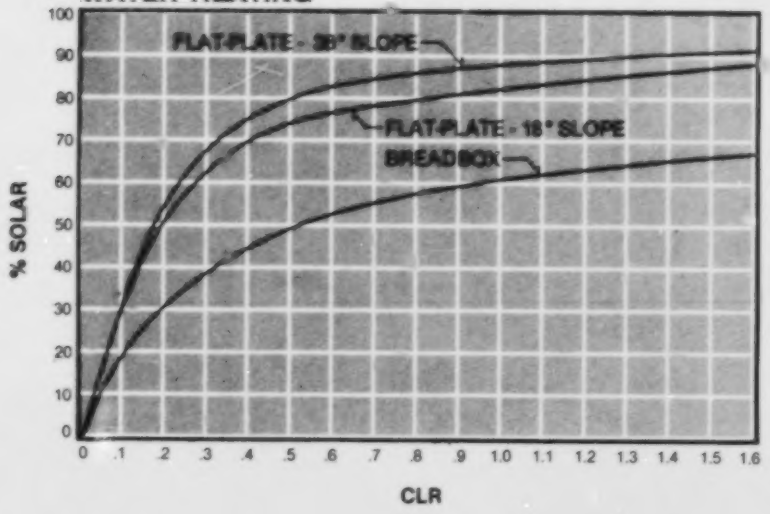
SPACE HEATING — 18° SLOPE



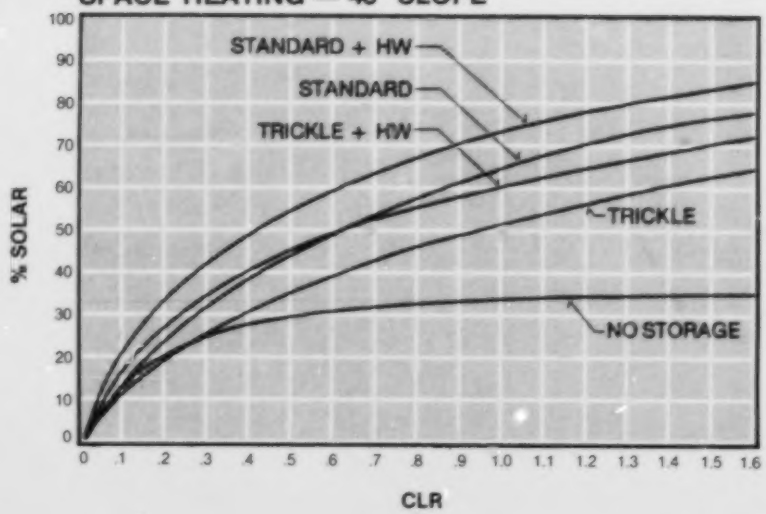
SPACE HEATING — 90° SLOPE



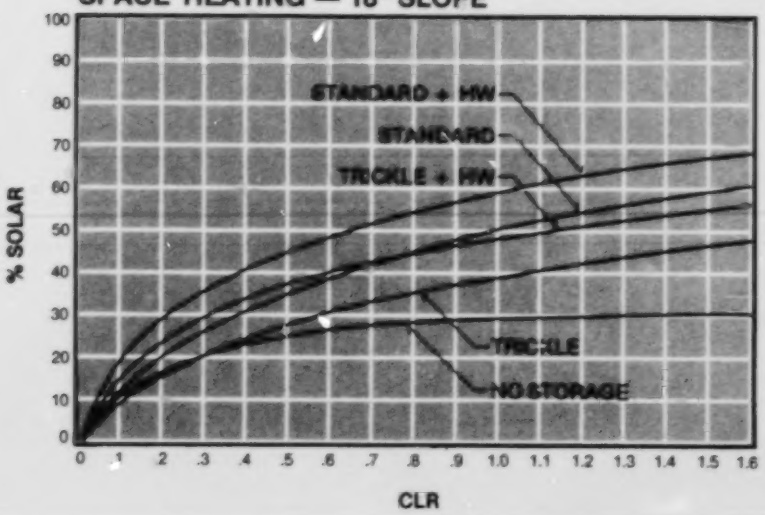
WATER HEATING



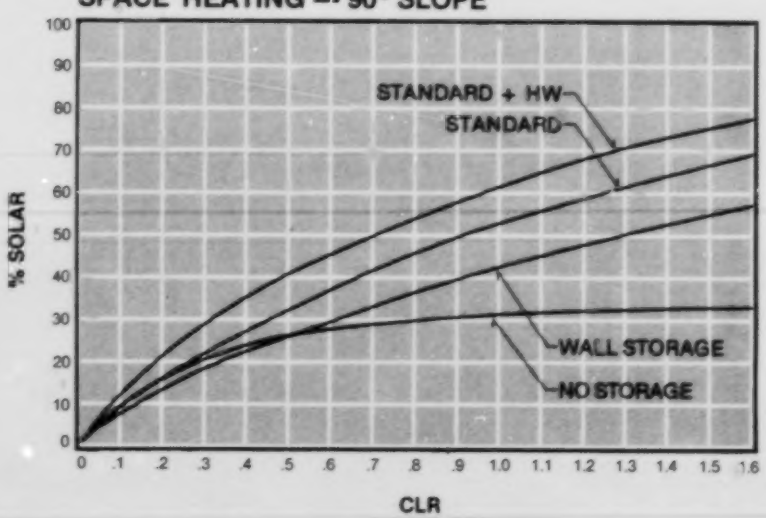
SPACE HEATING — 48° SLOPE



SPACE HEATING — 18° SLOPE



SPACE HEATING — 90° SLOPE



6: Solar Economics

There are many reasons – economic and otherwise – why people use solar energy. Some desire greater self-reliance, others are motivated by ecological considerations or wish to be the "first on the block" to use solar energy in their home. For many people, of course, the primary considerations are economic, especially the desire to save money on future fuel bills.

Even if your primary motivation for using solar energy is not an economic one, however, you still must decide whether you can *afford* the initial cost of the system you choose. So some kind of economic evaluation is necessary in any case. But the ways to evaluate the economic impacts of using solar energy are as varied as the reasons for using it.

In this chapter, we examine the costs and savings associated with the installation and use of solar energy systems. Worksheets are provided which enable you to determine the critical costs and savings for the system(s) of your choice. You should fill out a separate set of worksheets for each system you are considering, so photocopy them if you want to evaluate several systems. Sample filled-in worksheets are included to assist you in completing your own.

The primary orientation of this chapter is toward the homeowner. If you use solar energy in a business, you will probably capitalize the costs and depreciate them. This chapter will help you estimate those costs. As a homeowner, you can't offset the cost of home improvements against your income. When you file your state and federal income tax returns, there will be tax benefits for using solar energy. In particular, tax credits for solar installations and interest deductions (if you borrow money to pay for your system) will reduce both your federal and state income taxes.

Initial Cost, Loan Payments, and Income Tax Credits

If you don't need to borrow money to pay for your solar energy system, then the initial cost to you of installing it will consist of design fees, the cost of permits and approvals, and installation costs, including both labor and materials. If you do need to borrow money, your initial cost will be reduced by the amount of the loan, but you will have to make monthly loan payments. Financial incentives, such as tax credits, are increasingly available, and either reduce your initial cost or refund some of it to you at tax time. These are a lot of considerations to juggle, so use Worksheet 9 to help you calculate the initial cost to you of the system you've chosen. Refer to Sample Worksheet 9 on page 94 for guidance.

Initial cost

- Line 1: Design Cost
  These costs can be as high as 10% (or more) of the cost of the system, if the design services provided involve designing the system, preparing working drawings, and supervising construction. For a large active space heating system, that comes to a considerable sum. On the other hand, if you design the system yourself, the design costs may be zero, or somewhere in between the two extremes if you get your design work evaluated by a solar consultant.

  If you plan to hire someone to design your system or to check your own design work, find out what these services are going to cost. Enter this estimate on Line 1.

- Line 2: Permits and Approvals Cost
  Building permits will usually be required by the city or county before you install your system. The types of permits (plumbing, electrical, construction, etc.) and their costs vary. Generally they are based on the total installation cost, but they also depend on the type of system. For example, a thermosiphon water heater has no pump or controls, so an electrical permit may not be required.

  Many cities also require approval from some type of architectural review board. At least one solar project in the Bay Area ran into problems because of the appearance of the collectors and the exterior plumbing. The system's appearance can generally be modified without altering the functioning of the basic system. Still, your best bet is to check with your city or county building department *before* you make a final decision about the type of system you want to install. You may decide to change your plans to fit local requirements.

Worksheet 9:

Initial Cost; Loan Payments; State Income Tax Credit

Initial Cost

1. Design cost — $ 100 (1)
2. Permits and approvals cost — $ 20 (2)
3. Installation Cost: $24 (cost per sq. ft. (Chapter 4)) × 70 (Installed Area (Chapter 5)) = $ 1680 (3)
4. Total System Cost: *Add Lines 1, 2, and 3.* — $ 1800 (4)
5. Money borrowed (less any loan fees) — $ 1200 (5)
6. Initial Cost: *Subtract Line 5 from Line 4.* — $ 600 (6)
7. Loan Payments (from Table 6-1) — $ 334 (7)

State Income Tax Credit (for active systems only)

8. 55% of Total System Cost
   1800 (4) × .55 = $ 990 (8)
9. Tax Credit
   Enter the smaller of Line 8 and $3000. — $ 990 (9)

The system was designed by the owner, with a solar consultant hired to check the design.

The system is a high quality, flat-plate water heater, contractor installed.

$1,250 was borrowed, but a $50 loan fee reduced the amount actually received to $1,200.

A $1,250 loan at 12% interest for 5 years has these Loan Payments.

Since Line 9 is smaller than $3000, the entire 55% tax credit may be taken.

The cost of building permits and other forms of institutional approval is usually quite low ($50 or less). The cost of *satisfying the requirements* to get a permit, however, can be significant; for example, you may have to hire an engineer to do structural calculations.

Find out from the building department or the person you intend to hire what the permits or necessary services will cost. Enter the amount on Line 2.

- Line 3: Installation Cost
  Refer to the System Comparison Table on page 76. The lines headed "Cost per sq. ft. of installed area" contain estimated installation costs for the various systems. A cost range is shown because the installation cost depends on a number of things, including the type of system used, its size, the extent to which it's necessary to modify your building, and whether the system is owner or contractor installed. In general, a water heating system costs $20-35 per square foot of collection area if you hire someone to install it, about one-third less if you do it yourself. The cost of the larger systems required for space heating is less per square foot of collection area, and labor costs usually make up about 50% of the total.

  If you are planning to build the system yourself, look on the line in the System Comparison Table labled "Do-it-yourself," which includes only material costs. If you plan to hire a contractor, look on the "Contractor installed" line, which includes both labor and material costs. *To get the installation cost, multiply the cost per square foot from the System Comparison Table by the Installed Area in square feet (from Column K of Worksheet 8). Enter the result on Line 3.*

  It's possible to get a more precise cost estimate than the one derived from the System Comparison Table by actually pricing the materials and components you'd use to build the system yourself or by getting estimates from solar contractors. Enter these figures on Line 3.

- Line 4: Total System Cost
  Add Lines 1, 2, and 3. The result is the total cash price for the system. The only cost not included is interest on any money you borrow.

- Line 5: Money Borrowed
  Financial institutions generally are treating a solar energy system installation as just another home improvement project—their main concern is whether you can afford to make the payments. Shop around for loans, though. Savings and loan associations, credit unions, and banks don't all charge the same interest rate. Also, if you can incorporate your solar installation into a larger home improvement project, such as building an addition, then the financing of the solar portion of the project will be buried in a larger loan. This generally results in better terms. Check out all the possibilities, and you almost certainly will save yourself some money.

  If you borrow less than the full installation cost of the system, you still will have to make an initial or down payment. You may also be charged loan fees (or "points") by the lending institution, which will reduce the amount of money you actually get. *Subtract any loan fees from the amount of the loan and enter the result on Line 5. If you don't borrow money, enter zero.*

- Line 6: Initial Cost
  If Line 5 is smaller than Line 4, then subtract it from Line 4 to find the initial payment you still will have to make. Enter the result on Line 6. If that amount is too high, you'll have to increase the amount of the loan or reduce the cost of the system.

Loan payments

If you do borrow money, you'll have to make monthly loan payments. These payments are fixed in amount over the term of the loan. While each payment is small relative to the installation cost, the annual total cost of 12 monthly payments can be quite large. Also, don't forget that the interest you pay will add considerably to the total cost of the system, even though it is deductible on your state and federal income tax returns. We'll refer to the total annual cost as the "Loan Payments." Now continue on with Worksheet 9.

- Line 7: Loan Payments

  Table 6-1, below, will help you determine your Loan Payments. Each entry is the annual total of the monthly payments you will have to make if you borrow $1,000 *at that particular interest rate and term.* To determine your Loan Payments, first find the entry for your interest rate and term, then multiply it times the number of $1,000's you plan to borrow. For example, if it looks as if you'd borrow $3,500 at 10% for 15 years, then multiply $129 by 3.5 to determine your Loan Payments of $452 per year. *Enter the result on Line 7.* Since the amount of your monthly payment stays the same throughout the term of the loan, your Loan Payments will be the same each year.

Table 6-1

Loan Payments for a $1,000 loan at various interest rates and terms

Interest rate	Term		
	5 Years	10 Years	15 Years
8%	$243	$146	$115
10%	$254	$159	$129
12%	$267	$172	$144
14%	$279	$186	$160
16%	$292	$201	$176

State income tax credit

When you prepared your last California income tax return, you may have noticed references to the solar energy tax credit. The credit is 55% of the system cost – up to a maximum credit of $3000. (There is an additional allowance for large systems on buildings other than houses. We'll confine the discussion here to houses; check your income tax booklet if you want more information about other situations.) The credit will be in effect through 1980 and applies to all types of systems – active and passive, contractor-installed, and do-it-yourself.

Note that this is a direct credit against your state income tax, not a deduction. So you still have to come up with the initial cost, but your total cost will be lower since you get up to 55% of the installation cost back in the form of reduced state taxes. If your tax credit works out to an amount larger than the current year's taxes, you can carry the remaining amount forward to the next year(s).

To claim the credit, you must fill out and file with your state income tax return a Form 3805L. This form is available from the Franchise Tax Board; you can have one sent to you by calling 800/852-7700. The California Energy Commission has issued regulations about what costs can be included when you calculate your tax credit. There are also requirements concerning warranties and system performance that must be met. *Obtain and read* these regulations before you fill out the Form 3805L. The regulations are available from:

California Energy Commission
1111 Howe Avenue
Sacramento, CA 95825
800/852-7516

To get a rough idea of what your tax credit will be, use Lines 8 and 9 of Worksheet 9.

- Line 8: *Determine your maximum potential credit by multiplying the amount on Line 4 times .55. Enter the result on Line 8.*
- Line 9: Tax Credit
  Enter the amount on Line 8 or $3000, whichever is smaller. This is your actual Tax Credit.

There is also a federal solar tax credit being considered in Congress. The regulations for the California credit provide that if a federal credit is enacted, the combined federal and state credits may not exceed the state limitations. Therefore, the amount shown on Line 9 of Worksheet 9 is the maximum solar tax credit you can expect. However, there may be other benefits available to you in the future for non-solar energy conservation measures. Check with the organizations listed on page 113 for up-to-date information on energy-related tax benefits.

Reducing the initial cost

Now that you've finished Worksheet 9, you have an estimate of what the initial cost of the system will be and any resulting state income tax credit. If the initial cost (or the amount you will have to borrow) is more than you want to spend, set Worksheet 9 aside for a moment. Most of your initial cost is the installation cost. Let's discuss various ways to reduce it. In general, these measures apply to water heating, space heating, and pool heating systems alike.

- *Conserve energy.* We've already discussed energy conservation—we just want to remind you that it's generally much cheaper to *save* energy with simple conservation measures than to *provide* it with a solar heating system.

  Now that you have an estimate of your system's cost, it might pay to re-read the discussion of energy conservation in Chapter 2 and think about measures you passed up the first time around. If you can make additional savings, recalculate the amount of energy a solar system must provide using Worksheet 6 in Chapter 2. Use the reduced demand in Worksheet 8, Chapter 5, to determine the smaller collection area required to provide the same % Solar. Compare the savings in installation cost with the cost of the additional energy conservation measures to find out whether these measures would save you money.

- *Build it yourself.* If you do, you pay only for materials. Buy them wholesale if you can, but even at retail prices you'll save 1/3 to 1/2 of the installation cost.

- *Use recycled materials.* Material costs can be substantially reduced if you're willing and able to use second-hand materials. Many systems have been built incorporating used water heaters as tanks, sliding glass door "seconds" as glazing, and used lumber for framing. Note system #6 in the Bay Area Retrofit Survey (Appendix 3)—a solar water heater built for $50 using second-hand materials.

- *Use a smaller collection area.* A smaller collection area will reduce your installation cost, but it also will lower the % Solar provided by the system.

- *Modify your system.* See what money-saving changes you can make in the design of your system. For example, it may be possible to use a thermosiphoning system instead of a pumped one, eliminating the need for a pump and controls. The $150 initial cost and subsequent operating expense saved, however, would be partially offset because of the need for larger diameter pipes.

- *Switch to a different system.* In some cases, you may be able to get the same or a greater % Solar at lower cost by using a different type of system. Alternatively, a different system might provide a lower % Solar, but at lower cost than a smaller version of the original system. For example, it's difficult for a greenhouse to provide 70% of your space heating needs the way an active system can, but a greenhouse can often provide 30% at lower cost than an active system could.

  It's often wise to begin with a simple, inexpensive system. In general, the least expensive systems you can install are water heating systems, with passive space heating next, and active space heating systems the most expensive. Also consider installing two simple and less expensive systems of different types (such as a breadbox water heater and a greenhouse) instead of one larger, more complex and expensive system (such as a combined water and space heating active system).

If you come up with a new cost per square foot or a smaller collection area for your system by using one or more of the above measures, return to Worksheet 9. Use the new estimate to recalculate your cost.

Operating and Maintenance Costs

Worksheet 10 will help you estimate the cost of the energy required to operate your system (if it has pumps, fans, controls, etc.), the cost of maintaining it, and the cost of increasing your homeowners insurance (if necessary) so you can replace the system if your house burns down. These costs occur not only in the first year, but each year in the future. As these are continuing costs, you first must decide over what period of time you want to evaluate your system.

System lifetime

Do you want to evaluate the use of a particular solar energy system over a 10-year period? 15 years? 20? Worksheet 10 provides for a 20-year calculation, but you can use a longer or shorter period. If you use a longer period, you'll have to extend Worksheet 10.

The time period you use should be related to the system's expected lifetime, which is primarily a function of the materials used in the system and the quality of its design and construction. It's no good looking at a 20 year period if the system is likely to last only 10. In general, it's a good idea to use a system with a long life—the main cost of a system is its initial cost, and the savings get larger each year as the costs of conventional fuels increase. The longer your system lasts, the greater the savings will be. Discuss your plans with a solar consultant to get an estimate of your system's life.

How to use Worksheet 10

- Column F: *Note the time period you select by circling the last year of the period in Column F.*
- Column A: *Enter the Installation Cost from Line 3 of Worksheet 9.*
- Column B: Operating and Maintenance Factor
  Many systems have no operating cost, such as breadbox water heaters, thermosiphon systems, drum walls, and Trombe walls and greenhouse systems without fans. For systems that do have pumps, fans, or controls, the cost of the electricity used to operate them is usually very low, often only about $20 annually.

  Maintenance costs are variable and difficult to predict. Some systems require annual maintenance, such as adding fresh antifreeze or corrosion inhibitors, while others need virtually no attention beyond periodically cleaning the glazing. In general, active systems require more maintenance than passive systems because pumps, fans, controls, and anything else with moving parts need attention and will eventually have to be replaced. Systems using air tend to require less maintenance than systems using water; this is true for both passive and active systems. You'd be wise to select a system that probably will require little maintenance and replacement of parts—and get a reliable warranty, as you should for any type of heating system you have installed in your home or business.

  The trend appears to be toward exempting solar systems from local property taxes, so we have not included them in our estimate of continuing costs.

  Since passive systems generally have lower overall operating and maintenance costs than active ones, we've estimated these costs at 1% of the installation cost for passive systems and 2% of the installation cost for active systems. *If you plan to use a passive system, enter .01 in Column B; if you plan to use an active system, enter .02 in column B.*
- Column C: *Multiply Column A times Column B. The result is your operating and maintenance cost in Year 1, the first year you use your system. Enter it in Column C. If this figure looks unreasonable to you, substitute your own estimate. For instance, you may plan to do all your own maintenance on a system with no operating cost. In that case, enter a smaller amount in Column C.*
- Column D: Inflation Factor
  The cost in Year 1 will increase in each succeeding year due to inflation. The Inflation Factors in Column D are based on a 6% annual inflation rate. They show how much something costing $1 the first year would cost in each succeeding year *at that inflation rate.*
- Column E: Operating and Maintenance Costs
  Multiply the amount in Column C times the Inflation Factors in Column D to determine the operating and maintenance costs in future years. Enter the resulting figures in Column E.

Worksheet 10:

Operating and Maintenance Costs

A. Installation Cost (Worksheet 9)		B. Operating and Maintenance Factor		C.		D. Inflation Factor		E. Operating and Maintenance Costs	F. Year
1680	x	.02	=	$34	x	1.00	=	$34	1
					x	1.06	=	36	2
					x	1.12	=	38	3
					x	1.19	=	40	4
					x	1.26	=	43	5
					x	1.34	=	45	6
					x	1.42	=	48	7
					x	1.50	=	51	8
					x	1.59	=	54	9
					x	1.69	=	57	10
					x	1.79	=	61	11
					x	1.90	=	65	12
					x	2.01	=	68	13
					x	2.13	=	73	14
					x	2.26	=	77	15
					x	2.39	=	81	16
					x	2.54	=	86	17
					x	2.69	=	92	18
					x	2.85	=	97	19
					x	3.03	=	103	20

Operating and Maintenance Factors	
Active systems	.02
Passive systems	.01

From Sample Worksheet 9, Line 3.

The system is an active system, so .02 is used as the Operating and Maintenance Factor.

The operating and maintenance cost in each year – use these in Worksheet 12.

Inflation Factors for a 6% annual inflation rate.

A 20-year period was selected.

Savings

The major benefit of using solar energy is the money you will save each year on your fuel bills. Initially these savings may not be very large, but fuel prices have been increasing rapidly the past few years and are expected to continue doing so in the future. Thus the difference in your fuel bills if you use solar energy as compared to using only your existing systems will continue to increase each year, and that means increased savings. Use Worksheet 11 to find out what your savings will be.

First, however, a word to people who are planning to install a solar energy system or systems that would displace existing systems *which use different fuels.* For example, you may be planning to install a combined water heating/space heating active system to provide heating now done by an electric water heater and a gas furnace. Since you use two different fuels, you must use a separate copy of Worksheet 11 to calculate the costs and savings of using solar energy in relation to each fuel.

How to use Worksheet 11

- *Write the type of fuel your solar system will displace in the space provided on Worksheet 11.*
- Column H: *Circle the last year of the time period you have selected.*
- Column A: Energy Cost
  Determine the average amount you pay per unit of the displaced fuel (therm of natural gas, KWH of electricity, or gallon of propane or fuel oil). *To do that, divide the total number of units of that fuel on your two most recent utility bills into the total amount you paid for that fuel. Enter the result in Column A.*
- Column B: Conversion Factors
  The Conversion Factors in Column B enable you to determine the *cost per therm* of KWHs of electricity and gallons of propane or fuel oil. The factors take into account the relationship between the different units by which the fuels are measured and also adjust for the different efficiencies in the use of each fuel. *Enter the Conversion Factor corresponding to the type of fuel your solar system will displace in Column B.*
- Column C: *Multiply Column A times Column B.* The result is the effective cost per therm of the fuel your solar energy system will displace. *Enter the result in Column C.*
- Column D: Energy Saving
  Enter the Energy Saving from Column I of Worksheet 8 (see Chapter 5) in Column D of Worksheet 11.
- Column E: *Multiply Column C times Column D, and enter the result in Column E.* This is the amount your annual fuel bill will be reduced in Year 1 because of the solar energy system.
- Column F: Fuel Inflation Factors
  The Energy Cost in Year 1 will increase in each succeeding year as fuel prices rise, so the amount of money you save will increase each year as well. The Fuel Inflation Factors in Table 6-2 enable you to calculate what your savings will be in future years. The factors are based on a spring 1977 estimate by the Energy Commission of how fast fuel prices will rise in the PGandE service area.

Table 6-2

Fuel Inflation Factors

Years	Natural gas, propane, and fuel oil	Electricity
1	1.00	1.00
2	1.14	1.11
3	1.31	1.20
4	1.50	1.31
5	1.71	1.44
6	1.96	1.57
7	2.14	1.72
8	2.33	1.89
9	2.55	2.07
10	2.79	2.26
11	3.04	2.48
12	3.28	2.61
13	3.54	2.76
14	3.81	2.91
15	4.11	3.07
16	4.43	3.24
17	4.79	3.42
18	5.19	3.61
19	5.61	3.80
20	6.08	4.01

Based on a Spring 1977 estimate of the Energy Commission.

Worksheet 11:

Savings

Type of fuel: _____

A. Energy Cost		B. Conversion Factor		C.		D. Energy Saving (Worksheet 8)		E.		F. Fuel Inflation Factor (Table 6-2)		G. Saving	H. Year
$ 0.08	×	29	=	$ 2.16	×	91	=	$ 196	×	1.00	=	$ 196	1
									×	1.11	=	218	2
									×	1.20	=	127	3
									×	1.31	=	139	4
									×	1.44	=	153	5
									×	1.57	=	166	6
									×	1.72	=	182	7
									×	1.89	=	200	8
									×	2.07	=	219	9
									×	2.26	=	240	10
									×	2.48	=	263	11
									×	2.72	=	288	12
									×	2.98	=	315	13
									×	3.28	=	347	14
									×	3.60	=	381	15
									×	3.95	=	418	16
									×	4.34	=	459	17
									×	4.77	=	504	18
									×	5.24	=	554	19
									×	5.76	=	609	20

Conversion Factors	
Natural gas	1.4
Electricity	29
Propane	1.5
Fuel oil	1.2

The existing water uses electricity so the Conversion Factor 29 was used here.

The average cost per KWH.

The effective cost per therm of the fuel saved by the solar water heater.

91 therms from Column I of Sample Worksheet 8.

The inflation rate for electricity from Table 6-2.

The amount of money saved in each year — use these in Sample Worksheet 12.

Sample Worksheet 11

It is extremely difficult, however, to estimate future energy costs because of the political, as well as economic, factors that influence them. Revised estimates appear regularly. Because of the uncertainty of future energy prices and their critical importance in evaluating the economic impact of using solar energy, we recommend you check with the Energy Assessment Division of the Energy Commission to get their most recent estimate of how fast energy costs will rise.

Choose the set of Fuel Inflation Factors from Table 6-2 for the fuel your solar energy system will displace. Enter the factors in Column F.

- Column G: Saving
  Multiply the Fuel Inflation Factors in Column F times the amount in Column E to determine how large your Saving will be in each future year.

Other benefits

There are two additional benefits of using a solar energy system. Because your conventional system will be used less (now that it's only a backup to your solar system), it will not require as much maintenance, and its components will not have to be replaced as often. This benefit will probably be small, however, and when it will occur is difficult to predict, so it has not been included in the calculations.

The other benefit is that the solar installation will probably increase the value and marketability of your property, especially if your system is well designed and built. In fact, keeping a record of your utility bills may facilitate the sale of your property at a good price. As your property value inflates in subsequent years, the value of your solar system may appreciate as well. This benefit might be substantial, but it is difficult to quantify and has no effect on your annual costs and benefits. Perhaps the best way to view any increase in equity that occurs is as an offset to any increases you might have in your property taxes as a result of having a higher valued home.

You've now determined what the costs and savings will be if you install and use a particular solar energy system, but what does that mean to *you*? First, use Worksheet 12 to gather in one place the results of Worksheets 9, 10, and 11. Make a separate copy of Worksheet 12 for each system you're considering using.

How to use Worksheet 12

- Column A: *Note the time period you selected by circling the last year of the period.*
- Column B: *Enter the Initial Cost from Line 6 of Worksheet 9.*
- Column C: *Enter the Loan Payments (if any) from Line 7 of Worksheet 9.*
- Column D: *Enter the Operating and Maintenance Costs from Column E of Worksheet 10.*
- Column E: *For each year, add the entries in Columns B, C, and D together to find the Total Cost in that year. Enter the results in Column E.*

  If you are going to claim a solar state income tax credit on the system being considered (see page 96), then you must adjust the Total Costs in the first year or years. *First, add Columns C and D together to find the Total Cost, then enter the Tax Credit from Line 9 of Worksheet 9 on the line below.* If you pay enough state income taxes to allow you to take the entire credit in the first year, *subtract the Tax Credit from the Total Cost to determine your net cost in Year 1.* If you do not pay enough taxes to allow you to take the entire credit in the first year, then you must estimate how much of the credit will be carried forward into subsequent years. *Estimate your state income tax for the next several years.* Your tax credit for each year can never be greater than your taxes, so *reduce each year's total cost in Column E by the estimated amount of your taxes for that year until you have taken your entire Tax Credit. In the last year of this adjustment, of course, use the remaining Tax Credit rather than your full estimated tax.*

- Column F: *Enter your Saving for each year from Column G of Worksheet 11.*

Sample Worksheet 12

Worksheet 12: Net Costs and Savings

A. Yr	B. Initial Cost	C. Loan Payments	D. Operating and Maintenance Costs	E. Total Costs	F. Savings	G. Net Cost (−) or Saving (+) (Inflated $)	H. Inflation Factor	I. Net Cost (−) or Saving (+) (Present $)	J. Discount Factor	K. Present Value
1	600	334	34	968						
		Tax Credit (Worksheet 9)		990						
				−22	106	128	.94	120		
2		334	36	370	118	−252	.89	−224		
3		334	38	372	127	−245	.84	−206		
4		334	40	374	139	−235	.79	−186		
5		334	43	377	153	−224	.75	−168		
6			45	45	166	121	.70	85		
7			48	48	182	134	.67	90		
8			51	51	200	149	.63	94		
9			54	54	219	165	.59	97		
10			57	57	240	183	.56	102		
11			61	61	263	202	.53	107		
12			65	65	277	212	.50	106		
13			68	68	293	225	.47	106		
14			73	73	309	235	.44	103		
15			77	77	325	248	.42	104		
16			81	81	343	262	.39	102		
17			86	86	363	277	.37	102		
18			92	92	383	291	.35	102		
19			97	97	403	306	.33	101		
20			103	103	425	322	.31	100		
						$2504		$337		
						Cost (−) or Saving (+) (inflated $)		Cost (−) or Saving (+) (present $)		Life-Cycle Cost or Saving

From Sample Worksheet 9, Line 6.

The Total Cost in Year 1 of $968 is reduced by the Tax Credit from Sample Worksheet 9, Line 9.

From Sample Worksheet 9, Line 7.

From Sample Worksheet 10.

From Sample Worksheet 11.

When comparing Columns E and F, think of the Total Costs as being negative, the Savings as being positive.

Inflation factors for a 6% annual inflation rate.

The value of your future saving in present dollars.

- Column G: *Compare Column F with Column E.* If the Total Cost in a particular year is greater than the Saving for that year, then you have a net cost and are spending more money on your energy requirements in that year as a result of installing a solar system than you would have if you had continued to rely solely on your existing system. If Columns E and F are equal, your economic situation is unchanged. If Column F is greater than Column E, then you have a net saving and your overall energy-related expenses have been reduced. *Enter the Net Cost or Saving for each year in Column G.*

- Column H: Inflation Factors
  Most solar energy systems have a high initial cost (relative to conventional systems), but much lower operating and fuel costs over the life of the system, so the costs occur primarily during the first year (and during the term of any loan required), while the savings often don't get substantial until some time has passed. In addition, a $200 savings 10 years from now (future dollars) will not be worth as much as a $200 savings this year (present dollars) because of inflation. To understand better what your future savings will be "worth" in terms of present purchasing power, therefore, the Net Cost or Saving (Inflated Dollars) in each year should be adjusted for inflation, reducing it to present dollars. The Inflation Factors listed in Column H of Worksheet 12 will help you do this.

  Multiply each Inflation Factor times the corresponding entry in Column G. The result is what that future amount will be worth in terms of present dollars, *assuming an average inflation rate of 6%. Enter the results in Column I.* Notice how little a dollar will be worth in the future, but remember also that your income generally will be rising each year as well.

Make your evaluation

Now let's use the results of the worksheets to address your economic concerns. There are several ways to do this, depending on what you need to know in order to decide whether or not to use solar energy and, if so, which system or combination of systems to use.

Initial Cost. Can you afford to install the solar energy system of your choice? If your primary motivation for using solar energy is self-reliance, an ecological conscience, or status, the answer to this question is probably all you need to know. You've already decided to use solar energy – the only question is whether you can afford the system's *initial cost.*

Worksheet 9 enabled you to see what the initial cost will be. You must look at your personal economic situation and decide whether you can afford that cost. If you can pay for the system without borrowing, that's good. If you can't afford it, and can't figure out how to reduce the initial cost any further, you'll need to consider getting a loan.

How much *can* you afford to pay, in terms of both a down payment and monthly payments over a period of years? Worksheet 9 also lets you see what the initial cost will be if you borrow a particular amount, and Table 6-1 provided the corresponding Loan Payments. The combined costs in the first year will be the heaviest; if you can afford them, then all you have to worry about in subsequent years is making your monthly payments. If they are too high, shop around for a loan with a longer term. You'll pay more in total, but less each month. You might even find a lower interest rate. You could also borrow a smaller amount, although that increases the initial payment. So if your monthly payments might be a problem, you'll need to take a closer look at the costs and savings of using solar energy, particularly the saving from lowered monthly fuel bills.

Net Costs and Savings. An "economic" motivation for using solar energy assumes that you are looking for the most economical way to do space, water, or pool heating. If you view solar energy as a way of offsetting the rising costs of conventional fuels, then you need to compare all the costs and savings of using a solar energy system versus using only your existing system. This comparison needs to be done for a number of years. This will enable you to determine whether your solar system would improve your economic situation; in other words, whether it will reduce your fuel bills enough to

offset the cost of the system *and* increase the amount of money you have left to spend on other things. Worksheet 12 lets you make the necessary comparison.

- *Budgeting your income.* If your primary concern is how installing and using a solar energy system will affect your overall costs and savings in future years, the numbers in Column G of Worksheet 12 should tell you what you need to know.
- *Making an annual profit.* Look to Column G again to find out how long it will be before the savings begin to exceed the costs, and your system provides a net saving or profit.
- *Having a net saving over some period.* You can add up all the numbers in Column I (think of the net costs as being negative and the net benefits as being positive) to find the net cost or saving for the entire period.
- *Payback period.* You can also use Column I to determine the payback period for your solar installation by first adding up what annual net costs you have (generally for the initial year or years), then adding up the net savings in subsequent years until the total net savings equals the total net costs. Remember that after the payback period you will have recovered your initial outlay, but the savings will continue.

Your solar investment

You may think of solar energy as an investment, as just one of a number of ways in which you could use your capital to earn additional income. In this case, you may want to discount the net cost or saving in each year to find the present value of your solar investment. This is to reflect the sense in which $200 saved 10 years from now is worth less than $200 now, because you could invest approximately $93 now at 8% compounded monthly and, in 10 years, because of the interest, it would increase to $200. Therefore, $93 is the "present value" of the $200 future savings, assuming that particular interest rate and length of time.

The discount rate you choose should reflect the rates of return currently available to you on alternative investments. For example, if you can afford to tie up $1,000 or more for 4 to 10 years in a long-term savings account, you can earn an effective interest rate of about 8% on your investment. If you are in the 25% tax bracket, however, your after-tax rate of return will be only 6%; if the annual inflation rate is also 6%, your personal net discount rate actually will be zero. This means that if you invested $200 now, your investment would continue to be worth about $200 to you in the future, but no more. A shorter term savings account, earning 5.5% or 5.75% interest, may even have a *negative* net discount rate, which means that you'd have to invest *more* than $200 now to have $200 of purchasing power at some point in the future. Most people appear to have a personal discount rate close to zero or certainly no greater than 1 to 2%.

For those of you who want to consider discounting, we have provided Column J on Worksheet 12 ("Discount Factors") in which you can enter the discount factors for the net discount rate (adjusted for taxes and inflation) you choose. Determine the factor for each year by first subtracting your rate from 1.00, then multiplying the result times itself once for each year after the first. For example, if you feel that your net discount rate is 2%, subtract .02 from 1.00 to get .98. This is the discount factor for Year 1. Then multiply .98 times .98 to get .96, the discount factor for Year 2. Year 3 would be .94 (.98 times .96). Continue in this manner for all the years you want to consider.

Multiply the discount factors times the corresponding entries in Column I to find the present value of each year's net cost or saving. Enter the results in Column K. Add them up to find

the discounted present value of the net cost or saving for the time period chosen—this is the life-cycle cost or saving *of your solar installation.*

This value can now be compared to the returns available on alternative investments. Remember that the return on your solar investment is "tax free" as it is a savings, not income. In effect, solar savings are like the return on a tax-free municipal bond. To have available earnings of $200 from most investments, you would have to earn more than $200 so you could pay your income taxes and still have $200 left. For this reason, the present value of your solar savings should be compared to the *after-tax* earnings of alternative investments.

The sample Worksheets 9, 10, 11, and 12 show how to determine and compare the costs and savings associated with the installation of a solar water heater. We made the following key assumptions:

- An active system will be used with an Effective Area of 60 square feet and an Installed Area of 70 square feet.
- The system will be contractor-installed at a cost of $24 per square foot, with a design cost of $100 and a permit cost of $20.
- $1,250 will be borrowed at 12% for 5 years, with a $50 loan fee.
- The existing water heater uses electricity at an average cost per KWH of $.04.

How did this system turn out economically? Whether you can afford it is a personal decision and not totally an economic one. For example, how much is self-reliance, ecology, or status worth to you? If you are "buying" these values with your solar system, you may find a certain net cost is quite acceptable. You might also be satisfied knowing that the value and marketability of your building has increased, even if you can't say just how much.

If your motivation is an economic one, however, you want a net saving, either annually after some point or net over some period. In the sample Worksheet 12:

- The first year shows a net saving, because of the solar state income tax credit. The next four years show a net cost due to loan payments. Starting in Year 6 there is an increasing net saving.
- Column I shows that there is a net saving of $837 over the 20 year period if you reduce future savings to present dollars to compensate for inflation.
- The numbers in Column I show a total net saving after 12 years. This is the payback period for the system.

Let's change the example in selected ways and see how that affects the resulting economic situation.

- If the existing water heater uses natural gas, propane, or fuel oil, your net costs will be larger (and your eventual net savings smaller) in each year than when electricity is the displaced fuel. This is especially true if you now use natural gas. People now using electricity and, to a lesser extent, propane or fuel oil are in a favorable situation when it comes to converting to solar energy.
- If you pay for the system without borrowing, the Total Cost in Year 1 is large ($884 after the solar state income tax credit), but that's it. Net savings start in Year 2 and total $1116 in present dollars after 20 years. The payback period will be about 10 years, neglecting the interest you could have earned on savings.
- If your tax situation requires that you carry some of the Tax Credit beyond Year 1, the Total Cost will be higher in Year 1 and lower in the "carry over" years. The long-term effect of this is small, but the higher Year 1 Total Cost may mean you have to borrow extra money or reduce the size of your system.
- Finally, consider what happens if you build the system yourself. Assuming you save 40% of the installation cost, Worksheet 9 now shows an initial cost of $1,128. The lower initial cost means it's less likely you'll have to borrow to pay for the system; even if you do, your Loan Payments will be lower as well. So you're also in a very favorable situation when it comes to using solar energy if you can build your own system.

In any case, it's time to get started. Chapter 7 tells you how.

7: Getting Started

Can You Do-It-Yourself?

At this point, we hope that you have decided that you can and want to use solar energy. The problem now is how to get started.

You've already been involved in the preliminary design of your system – that's what this book is about. A major decision you now have to make is whether you want to continue to do the detailed design and construction yourself or whether you'd be wiser to hire people to help you. The first three sections in this chapter provide general advice and information that should help you both make up your mind and act successfully on your decision.

If you decide to do it yourself, you'll need more detailed design and construction information than we've provided in this book. The remaining sections in this chapter and all of Chapter 8 tell you how and where to get it. In general, we recommend the following:

- Read additional solar literature
- Take solar classes
- Visit existing solar installations
- Join solar organizations
- Use solar information centers and agencies

Even if you decide to hire a solar consultant or contractor, there is much in these remaining sections that will be of interest and value to you. Remember that your best assurance of getting a high quality solar installation is to be an informed consumer.

To answer this question, you'll need to learn more about your planned system and then honestly evaluate your ability to design and build it.

Learn more about the system you're considering

There are at least three means of doing this: taking one of the local classes on solar energy use (see "Classes," page 111), attending lectures offered by professionals or do-it-yourselfers in the field (see NCSEA, page 113), or reading books and inspecting system plans related to the project you're considering (see Chapter 8). You will be able to find out more specific information on cost, components used, and the "things to watch out for" in building your system from people who've had direct solar experience. If you're interested only in one particular system, call the class instructor or get the NCSEA newsletter to find out if and when that particular system will be covered.

Evaluate your ability

You must honestly ask yourself whether you have enough time, skills, and energy to design and build your own system. If you want to start small, this really isn't a problem. Even if you don't have any design or construction skills to speak of, you can still try a project like a window box air heater or a small breadbox water heater. Find a friend willing to put in the small amount of time required to help you with the carpentry and plumbing details. You'll learn a lot, have a solar system to show for your efforts, and won't risk much money or time in the process.

Larger projects are another matter. There are three aspects to getting them done:

- Design
- Construction and installation
- Management

The System Comparison Table on page 76 gives you an idea of the skills required for the first two aspects of a solar project. Compare the skills listed in the Table to the skills you have to find out what you're equipped to do and what you'd have to hire out. We've also included the aspect of management. For a complicated project, such as an active house heating system, you'll need to be thoroughly familiar with what needs to be bought and get built (and in what order) to be able to get the project organized and completed.

It's not necessary, however, to be able to do everything. Even if you contract the job out, you can still save money (especially on space heating systems) by doing preparatory work for the contractor or even by running errands.

The main thing is to be careful not to overestimate your abilities, particularly for doing an active system. It's one thing to launch into a toaster repair and find out you can't get as many parts back in as you took out—toasters are cheap to replace. It's something else to end up with a half-assembled, unusable collector in the back yard, instead of a completed one up on the roof, after spending a lot of money for materials. Even if you do finish the job, the components in a solar system must function well for a long period of time. Small mistakes in design or construction can reduce the performance of an entire system or lead to increased maintenance and replacement costs.

It's worth noting that the skills required and the risk of the completed system not performing well are generally not as great with passive systems as with active systems. For example, building a room addition to house a drum wall is a fairly extensive project, but the carpentry skills required are more common than the skills required to construct an active space heating system.

Getting help with your design

If you design the system yourself, it's worth hiring a knowledgeable engineer, architect, or solar consultant to look over your plans. Probably the best approach is to talk to someone when you're beginning your design. Decide on the type of system you want to use, then check back several times as you develop the design. That way you won't spend months completing your design, only to have the consultant inform you that it won't work without substantial modifications. The fee for this sort of service should be $50 to $500, depending on the type of system you're designing and how much you can do yourself. To find a consultant, talk to people who have already had systems installed, look in the Yellow Pages under "Solar," go to meetings of the NCSEA (see p. 113), check with the "Information Centers" (see p. 114), or look in the consumer directories listed in Chapter 8, Section C.

Plans and kits

One way to reduce the amount of design work required is to buy a set of plans for your system. Most of the plans on the market are inexpensive (see Chapter 8, section E), and it's often worth buying several different sets so you can compare them and get ideas.

Kits are more expensive than plans and also difficult to evaluate sight unseen. Before you buy, write for a copy of the assembly instructions. Run through the assembly in your mind. If the instructions don't make sense or are too difficult to follow, select another kit and follow the same procedure. Also, pay attention to what the kit includes and what it doesn't. Important and expensive components may have been omitted.

Buying materials

Most solar systems are composed largely of ordinary building materials such as lumber and sheet metal, and ordinary plumbing, electrical, and ventilating equipment such as pipe, pumps, fans, and ducts. These are available from your local lumber yards, plumbing and heating suppliers, or large general department stores such as Sears or Montgomery Ward.

Finding the specialized solar equipment required for a system was not easy up to now, since the products were not widely available. However, solar stores are beginning to open in or near the Bay Area. Two are:

The Solar Center
62 Townsend Street
San Francisco, CA 94107
415/957-9660

Solar Access
320 Cedar Street
Santa Cruz, CA 95060
408/426-3100

Some plumbing suppliers are also beginning to carry flat-plate collectors, tanks, and other specialized solar hardware. You can also check with others working in the solar field for tips on what to use and where to find it.

Since solar energy is just getting going on a commercial basis, and the materials for your system may be quite expensive, exercise some caution when buying. Here are a couple of suggestions to keep in mind when buying materials (for more, see *Buying Solar*, reference C-1 in Chapter 8):

- *If there is a warranty, examine it carefully.* A manufacturer is legally required to state whether the warranty is full or limited. If it is limited, find out what the limitations are. How long does the warranty last? Are parts, service, and labor covered? Who will provide the service? Does the equipment have to be sent back to the manufacturer for repairs? Is its estimated life guaranteed to a reasonable extent?

  Make sure you understand the terms of the warranty before you buy. Ask the seller what financial arrangements, such as an escrow account, have been made to back the warranty.

  It is difficult to guarantee the performance of solar energy equipment and systems. If performance is guaranteed, be sure to get specific information on how and under what conditions it is to be measured.

- *Check references.* Ask the sellers of solar equipment for the names of previous purchasers. Get their opinions of the equipment. Does it work? Is it worth the money?

The major problem in hiring a contractor is finding one with solar energy system experience. For help, call the Solar Switchboard and the National Solar Heating and Cooling Information Cent[illegible]see "Information Centers," page 114), check the catalogs and directories referenced in Section C of Chapter 8, talk to solar consultants and to people who have had systems installed, and look in the Yellow Pages under "Solar."

It's always a good idea to check references on the people you are considering hiring. Any reputable contractor will furnish you with names of previous customers.

When you hire a contractor to do some or all of the job for you, make a clear agreement in writing, detailing exactly what is to be done and what it's going to cost. The contractor's license number, along with certain notices regarding "mechanic's liens," are required to be included in the contract. Any questions or complaints regarding Bay Area contractors should be referred to:

Contractors' State License Board
8301 Edgewater Drive
Oakland, CA 94621
415/464-0964

Be prepared to document your complaint.

For more information on hiring, refer to *California Sunshine* and *Buying Solar* (Chapter 8, references B-2 and C-1).

Classes

Classes on various aspects of solar energy are offered by the following educational institutions. We haven't included detailed descriptions of the courses since their content is likely to change with time. We have indicated the general orientation of each. Contact the teachers or institutions for up-to-date content, times, and prices.

California State University at San Jose

A homeowner-oriented course on practical solar energy systems and solar home design. Contact:

Continuing Education
California State University
San Jose, CA 95192

University of California, Berkeley

A two-day course for contractors, architects, engineers, owners, and builders on solar applications for houses, buildings, and pools, taught by Marshal Merriam and Berkeley Solar Group. Contact:

Continuing Education in Engineering
University Extension
University of California
2223 Fulton Street
Berkeley, CA 94720
415/642-4151

College of Marin, Adult Education

Interactive Resources, Inc. offers a general course on solar and other natural energy sources, such as wind. Contact:

Registrar's Office
(Adult Education Department)
College of Marin
Kentfield, CA 94904
415/454-3962

Farallones Institute Integral Urban House

A layperson's course covering basic theory, design, and construction of space and water heating systems for houses. Contact:

Integral Urban House
1516 5th Street
Berkeley, CA 94710
415/525-1150

Open Education Exchange

An introductory course on energy-efficient design and solar energy for houses. Contact:

Open Education Exchange
6526 Telegraph Avenue
Oakland, CA 94609
415/655-6791

Interactive Resources, Inc.

A two-day annual conference on solar applications for buildings. Oriented toward professionals. Contact:

Interactive Resources, Inc.
117 Park Place
Point Richmond, CA 94801
415/236-7435

The Solar Center

One- and two-day specialized courses for architects, contractors, realtors, and others. Also, a general public course on the design and construction of residential water and space heating systems.

The Solar Center
62 Townsend St.
San Francisco, CA 94107
415/957-9660

Additional Reading

One obvious way to get detailed design and construction information is to read additional books and articles on solar energy. The problem is knowing what to read. Chapter 8 is an annotated bibliography which will help you find the references most useful to you.

The Farallones Institute Integral Urban House

As discussed in Chapter 1, The Farallones Integral Urban House in Berkeley has a solar water heating system. You can see it, as well as the other "ecological household management" demonstration projects, by taking one of the tours of the house conducted every Saturday from 1-5 p.m. Self-guided tours are available on other days. A small donation is requested to support the research and educational activities at the house. Call for further information.

The Integral Urban House
Farallones Institute
1516 Fifth Street
Berkeley, CA 94710
415/525-1150

California State University at San Jose

Large solar water heating systems are being installed on the roofs of the Hoover, Royce, and Washburn residence halls at California State University at San Jose. The systems are being built by students at the University. When the systems are completed, the Center for Solar Energy Applications at CSUSJ will begin conducting tours, but you can see the work in progress from the top floor of the parking garage at 7th Street and San Carlos in San Jose. For further information, call:

Center for Solar Energy Applications
408/277-2939

State Parks

The State of California is retrofitting ranger residences at five state parks. This is part of the Solar Demonstration Program run by the U.S. Department of Housing and Urban Development. The houses will be open to the public. The residence at Wright's Beach, in Sonoma Coast State Park, is the only one of the houses in the Bay Area, but others are located at Donner Memorial and Prairie Creek State Parks, which are not far away. Contact the State Department of Parks and Recreation after September 1977 for further information.

PGandE demonstration homes

For solar systems involving space and pool heating, as well as water heating, see the Pacific Gas and Electric Company's solar homes in Walnut Creek and San Jose. These are new homes, not retrofits, and are not suitable for do-it-yourself projects, but are interesting nonetheless. For more information, contact Bill Seavy or Byron Woertz of PGandE at:

77 Beale Street
San Francisco, CA 94106
415/781-4211, ext. 3004 or 3811

The Farallones Institute Rural Center

The Rural Center in Occidental (Sonoma County) is the site of a breadbox water heater, a free-standing solar greenhouse, and four small buildings demonstrating various solar space heating systems. (These systems are not retrofits.) The Center's visiting policy has not been established, so you should write them a letter (include your address and phone number), telling them when you'd like to visit.

The Farallones Institute Rural Center
15290 Coleman Valley Road
Occidental, CA 95465

City of Santa Clara

The city government in Santa Clara has a very active solar energy program. Their Community Recreation Center is both heated and cooled by solar energy; tours can be arranged by calling Nick Davis or Robert Mortensen:

City of Santa Clara
Water Department
408/984-3183

In addition to the Recreation Center, two of the city's public swimming pools, Montague Park and the International Swim Center, will be solar heated. The water department also acts as a solar utility. Swimming pool owners can contract with the city for a solar heating system for their pools. There is an initial $200 fee for design and installation, then monthly payments for six months of the year.

NCSEA

The Northern California Solar Energy Association (NCSEA), a local chapter of the American Section of the International Solar Energy Society, meets the second Saturday in each month at various locations around the Bay Area. These meetings are open to the public and offer you an invaluable opportunity to meet and talk to other solar enthusiasts, both lay people and professionals. The meetings usually consist of several talks on solar-related subjects, followed by tours of local solar installations. Membership, at $10 a year or $5 for students, includes a monthly newsletter that contains meeting announcements, notes on activities, and solar news of general interest. Write to:

NCSEA
P.O. Box 1056
Mountain View, CA 94042

ISES

As you become more involved in solar projects, you may also wish to join the American Section of the International Solar Energy Society (ISES). Membership is $30 per year or $17 for students. For your membership fee you get information—the results of research and experience on an international scale—as contained in *Solar Energy*, a bimonthly technical journal; *Sunworld*, a quarterly journal of a less technical nature; *ISES News*, the newsletter of the international organization; *Solar News and Views*, the newsletter of American Section activities; and reduced rates on the proceedings of the annual meetings, held in different cities throughout North America. For further information on ISES, write:

Howard P. Harrenstein, Secretary-Treasurer
American Section, ISES
c/o Florida Solar Energy Center
300 State Road 401
Cape Canaveral, FL 32920

SUNRAE and Solar Energy Advocates

If you are interested in the political side of the energy issue, you might be interested in SUNRAE and Solar Energy Advocates. They are active lobbyists for solar energy in California. SUNRAE has available a list of all the solar legislation that has been introduced in the state legislature and is working on a larger list covering legislation in other states. They also have compiled a list of solar manufacturers in California, which they sell for $2.00. Membership, at $15 a year or $5 for students and seniors, includes the manufacturers' list and a newsletter. Contact:

SUNRAE
1902 Vine
Berkeley, CA 94709
415/527-6659 (Antoinette Azevedo)

-or-

2317 Elendil Lane
Davis, CA 95616
916/756-8873 (Alan Mirviss)

Membership in Solar Energy Advocates costs $5 per year, for which you receive a monthly newsletter reporting on pending solar legislation and solar events. Contact:

Solar Energy Advocates
P.O. Box 876
Sacramento, CA 95814
916/446-4559

Information Centers

Solar Switchboard

The Solar Switchboard, operated by The Center for Solar Energy Applications at California State University at San Jose, has information available on everything from basic concepts of solar energy to specific applications. Call them for lists of consultants, manufacturers, builders, and architects, information on solar classes, reading lists, news, do-it-yourself information, and answers to your questions. Telephone: 408/277-2939.

National Solar Heating and Cooling Information Center

This service is similar to the Solar Switchboard, but on a national scale. Call toll-free or write:

National Solar Heating and Cooling
Information Center
P.O. Box 1607
Rockville, Maryland 20850
800/523-2929

Energy Information Center

Although not primarily a solar energy information service, the Energy Information Center can provide you with several solar publications and information sources. Call or write for their solar package:

Energy Information Center
100 California Street
San Francisco, CA 94111
415/556-7328

California Energy Resources Conservation and Development Commission

The best way to keep up with the activities of the Energy Commission, including those relating to solar energy, is by reading the *State Energy Commission Newsletter*, available free from:

ERCDC
Office of Information and Education
1111 Howe Avenue
Sacramento, CA 95825

If you have specific questions about the State's solar energy program, contact the Alternatives Implementation Division of the Energy Commission at the above address.

8: Further Information

This chapter lists books, magazines, plans, and other sources of information which will be helpful to you in carrying out solar or energy conservation projects. We made no attempt to include every book relating to these subjects. Instead, this chapter contains the best sources we know of at various technical levels.

Each listing is annotated with our judgment about its strengths and weaknesses to help you select sources that best fit your needs. We have noted prices where possible and mailing addresses for materials available only by mail. Each listing also has a letter-number code next to it which is used in the preceding chapters to make references.

Most of materials listed are popular or technical books that can be bought at local bookstores or used at and sometimes borrowed from libraries. Here are some places to check in the Bay Area:

- Public libraries.
- Your local community college.
- California State University at Hayward, Sonoma, San Jose, and San Francisco.
- University of California at Berkeley and Davis.
- Stanford University.

Technical books are usually located with engineering or architecture collections. Access to them (and to library books in general) varies from place to place, so call first to find out what identification you may be required to bring.

If you want to buy a book, here's some leads on where to locate it:

- Non-technical solar books are often carried by local bookstores.
- There are good bookstores near most colleges and universities. Some of these carry technical books, as well as the more general references. Check the Yellow Pages and make some phone calls if you're looking for a specific book.
- Many of the publications sponsored by U.S. government agencies can be purchased at:

  U.S. Government Printing Office Bookstore
  450 Golden Gate Avenue
  San Francisco, CA 94102
  415/556-6657

- The following stores carry a large range of solar, conservation, and home improvement books:

  Whole Earth Access Co.
  2466 Shattuck Avenue
  Berkeley, CA 94704
  415/848-0527

  Whole Earth Truck Store
  558 Santa Cruz Avenue
  Menlo Park, CA 94025
  415/323-0313
  (The Truck Store also does mail orders. Write or phone them for information.)

A. Energy Use and Conservation

A-1: Bender, Tom. *Environmental Design Primer.* New York, N.Y.: Shocken Books, 1976. 207 pp. $6.

Significant reductions in our use of energy and resources will come about only as our environmental consciousness changes and matures. This provocative book challenges the attitudes and ideas that determine how we relate to our environment. The suggested alternatives move us toward a society in which energy conservation and solar energy would be the primary solution to our energy needs.

A-2: U.S. Department of Housing and Urban Development. *In the Bank . . . Or Up the Chimney? A Dollar and Cents Guide to Energy-Saving Home Improvements.* Radnor, PA: Chilton Book Co., 1975. 70 pp. $1.95. (Call the HUD library in San Francisco to get a copy.)

How to reduce the amount of energy you now use to heat and cool your home. Simple step-by-step instructions (with worksheets) for determining which measures will work, their cost and savings. Includes installation instructions, tool and material lists, tips on safety, using a contractor, and more.

A-3: Federal Energy Administration. *Home Energy Savers Workbook.* Washington, D.C.: FEA, 1976. $.50.

A 30 page booklet describing energy saving measures that can be used on existing homes. Worksheets are included for estimating annual fuel savings that would result from the recommended improvements.

A-4: U.S. Office of Economic Opportunity. *Save Energy: Save Money!* by Eugene Eccli and Sandra Fulton Eccli. Washington, D.C.: U.S. Government Printing Office, 1974. Free. (Call the Community Services Administration publications clerk in San Francisco to obtain a copy.)

Simple, illustrated discussion of energy conservation measures which reduce home heating (and cooling) costs.

A-5: Pacific Gas and Electric Co. You can get the following useful pamphlets free from your local PGandE office.

"Conservation Tips from PGandE" series:

1. *Cooling Your Home More Efficiently*
2. *For Your Refrigerator-Freezer*
3. *For Your Range*
4. *For Your Clothes Washer Or Dryer*
5. *For Your Automatic Dishwasher*

Energy Quiz
Air Conditioner Maintenance Checklist
Sun Energy
Insulate. Save Energy.

A-6: Adams, Anthony. *Your Energy-Efficient House; Building and Remodeling Ideas.* Charlotte, VT: Garden Way Publishing, 1975. 118 pp. $4.95.

An elementary but accurate presentation of energy conserving design ideas. Emphasis is on new construction, but much of the information is applicable to retrofit situations.

A-7: Eccli, Eugene, ed. *Low-Cost Energy-Efficient Shelter For The Owner And Builder.* Emmaus, PA: Rodale Press, 1976. 408 pp. $5.95.

Energy saving design ideas for the owner-builder, with information on financing and cost reduction. Good material on shutters and insulating curtains.

A-8: Hammond, Jonathan et al. *A Strategy for Energy Conservation—Proposed Energy Conservation and Solar Utilization Ordinance For the City of Davis, California.* Winters, CA: Living Systems, 1974. 51 pp. $5.00.

Although dealing primarily with new construction, the principles of natural climate control presented are applicable to existing buildings as well. Also interesting as an example of how a community can begin to deal with its own energy use.

A-9: California Department of Housing and Community Development. Division of Codes and Standards. *Energy Design Manual for Residential Buildings.* 2d printing. Sacramento: State of California, 1976. 129 pp. $3.43.

This provides the specific California climate information and the glazing and insulation standards required to meet the state Residential Energy Code. Useful as a how-to-do-it manual on heat loss calculations and insulation installation.

A-10: *ASHRAE Handbook and Product Directory.* 4 volumes: 1972 Handbook of Fundamentals, 1973 Systems, 1974 Applications, 1975 Equipment. New York: American Society of Heating, Refrigerating, and Air Conditioning Engineers. Expensive.

A comprehensive and technical reference on heating, refrigerating, air-conditioning and ventilating.

B. Solar and Other Alternative Energy

B-1: Daniels, Farrington. *Direct Use of the Sun's Energy.* Westminster, MD: Ballantine Books, 1964. 271 pp. $1.95.

One of the best available introductions to the subject. Covers all aspects of solar energy research and applications without stressing mathematical or engineering details; describes the full range of work on solar collectors, cooking, heating, agricultural and industrial drying, distillation, storage of heat, solar furnaces and engines, cooling and refrigeration, photochemical conversion, photo- and thermo-electric conversion, and many other uses of solar energy.

B-2: California Energy Resources Conservation and Development Commission. *California Sunshine, A Consumer Guide to Solar Energy,* by Interactive Resources, Inc. Sacramento: State of California, 1977.

A broad introduction to the principles and use of solar energy. Includes sections on economics (more complex than the approach in this book), where to go for further help, and a bibliography.

B-3: Merrill, Richard, et al. *Energy Primer.* Menlo Park: Portola Institute, 1974. 200 pp. $5.50. A revised edition will be available Fall 1977.

A comprehensive, fairly technical book about renewable forms of energy—solar, water, wind and biofuels. More than one quarter of the book is devoted to reviews of books and hardware sources, somewhat in the form of the Whole Earth Catalog. Illustrations and original articles are used to describe the workings of solar water heaters, space heaters and dryers, wind generators, wood burning heaters and methane digesters.

B-4: Leckie, Jim, et al. *Other Homes and Garbage; Designs for Self-Sufficient Living.* San Francisco, CA: Sierra Club Books, 1975. 302 pp. $9.95.

A practical introduction to energy-conserving design, wind power, solar heating, waste handling, water supply, and aquaculture for home-scale application. There are a number of inaccuracies in the solar material, so check details in other books.

B-5: Anderson, Bruce, and Michael Riordan. *The Solar Home Book.* Harrisville, NH: Cheshire Books, 1976. 297 pp. $7.50.

An excellent general book on home-scale solar applications. Aimed at the non-technical reader yet technically accurate and thorough. Retrofitting is not covered extensively, but most of the material in the book applies to it in one way or another.

B-6: Fisher, Rick, and Bill Yanda. *The Food and Heat Producing Solar Greenhouse; Design, Construction, Operation.* Santa Fe: John Muir Publications, 1976. 161 pp. $6.00.

A thorough treatment of all aspects of solar greenhouses. Includes a great deal of information on greenhouse operation that cannot be found elsewhere. Essential for those interested in greenhouses.

B-7: Foster, William M. *Homeowner's Guide to Solar Heating & Cooling.* Blue Ridge Summit, PA: Tab Books, 1976. 196 pp. $7.95.

A good complement to *Solar for Your Present Home* (this book). Goes into some depth on system components and operation, but the sizing and economic methods are less accurate than ours are. Good information on pool heating. Easy to read, good diagrams.

B-8: Yellott, John I., *et al. Solar Oriented Architecture.* Washington, D.C.: AIA Research Corporation, 1975. 142 pp. $15.00.

Summary descriptions of nearly 70 dwellings which receive part or all of their heat requirements from the sun. Also covers basic principles of solar space heating and gives detailed examples of principal methods of using solar energy.

B-9: U.S. Department of Housing and Urban Development. Office of Policy and Research. *Solar Dwelling Design Concepts,* by the AIA Research Corp. Washington, D.C.: U.S. Government Printing Office, 1976. 146 pp. $2.30.

An excellent introduction to the operation of active and passive solar systems. Includes numerous house designs which could provide ideas for retrofits.

B-10: Watson, Donald. *Designing & Building A Solar House.* Charlotte, VT: Garden Way Publishing, 1977. 281 pp. $8.95.

Not on retrofitting, but lots of solar ideas that can be used on existing buildings. Numerous photographs of solar houses finished and under construction. Good chapter on building a solar house.

B-11: Crowther, Richard L. *Sun/Earth; How to Use Solar and Climatic Energies Today.* Denver: A.B. Hirschfield, 1976. 232 pp. $12.95.

Another non-retrofit book that contains useful information on solar design. Some material on commercial buildings.

B-12: Solaron Corporation. *Application Engineering Manual.* Rev. ed. Commerce City, CO: Solaron Corporation, 1976. 89 pp. $15.00. (Available from Solaron Corp., 720 So. Colorado Blvd., Denver, CO 80222.)

Nuts and bolts information on air solar heating systems.

B-13: Los Alamos Scientific Laboratory. *Pacific Regional Solar Heating Handbook.* For ERDA San Francisco Operations Office. 2d ed. Washington, D.C.: U.S. Government Printing Office, 1976. 108 pp.

Covers the effects of varying system parameters (slope, orientation, storage size, etc.) on system performance. A collector sizing method is provided. Some technical background is assumed, but generally not essential.

B-14: Kreider, Jan F., and Frank Kreith. *Solar Heating and Cooling; Engineering, Practical Design, and Economics.* New York: McGraw-Hill, 1976. 342 pp. $22.00.

This is an intermediate-level book on solar engineering. Although mathematics are used extensively, the clear drawings make the book easier to understand than other engineering texts. Heat transfer, solar collectors, solar heating and cooling, and collector testing are covered.

B-15: Duffie, John A., and William A. Beckman. *Solar Energy Thermal Processes.* New York: John Wiley & Sons, 1974. 386 pp. $16.95.

The basic technical text on solar applications. Especially strong on heat transfer fundamentals and flat-plate collector engineering analysis. Very thorough references into the solar energy technical literature.

C. Consumer Information and Directories

C-1: U.S. Federal Energy Administration. *Buying Solar,* by Joe Dawson. Washington, D.C.: FEA, 1976. 71 pp. Free.

Operation of solar systems, comparison of air and water systems, economics, and discussion of performance guarantees. No discussion of passive systems.

There are numerous directories of people and businesses in solar energy. The first is the most local. We have no way of knowing how complete or up-to-date these directories are.

C-2: Southern California Solar Energy Association. *Western Regional Solar Energy Directory.* San Diego: San Diego Urban Observatory, 1976. 54 pp. $2.00. (Order from: SCSEA Directory, 202 "C" Street, 11B, San Diego, CA 92101.)

A listing of 500 companies and individuals involved in the solar energy industry in California and other western states. Includes architects, engineers, contractors, builders, solar consultants, manufacturers and distributors.

C-3: Solar Energy Industries Association, Inc. *Solar Energy Industry Directory and Buyer's Guide.* Washington, D.C.: SEIA, Inc., 1975. $2.00. (Order from SEIA, Inc., 1001 Connecticut Avenue, N.W., Washington, D.C.)

C-4: Pesko, Carolyn. *Solar Directory.* Ann Arbor: Ann Arbor Science Publishers, Inc., 1976. $20.00.

C-5: Shurcliff, William A. *Information Directory of Organizations and People Involved in the Solar Heating of Buildings.* Cambridge, MA: Shurcliff, 1975. About $6.00.

C-6: *Directory of the Solar Industry.* Hampton, NH: 1976. $7.50. (Available from Solar Data, 13 Evergreen Road, Hampton, NH 03842.)

C-7: U.S. Congress. Committee on Science and Technology. *Survey of Solar Energy Products and Services.* Washington, D.C.: Library of Congress, Science Policy Research Division, 1975. $4.60.

D. Periodicals

D-1: *Solar Age*
Solar Vision, Inc.
Box 288
Vernon, NJ 07462

Covers all aspects of solar energy, including wind, bioconversion, photovoltaics, etc. Information useful for do-it-yourselfers as well as commercial firms is presented, with emphasis on design considerations and existing solar buildings. Published monthly. $20 per year.

D-2: *Solar Engineering Magazine*
8435 N. Stemmons Freeway, Suite 880
Dallas, TX 75247

The official publication of the Solar Energy Industries Association. Regularly features legislative reports, news of the industry, and recently completed solar projects. Your best access to solar product literature. Published monthly. $10 per year.

D-3: *Solar Energy Digest*
P. O. Box 17776
San Diego, CA 92117

Reports developments in solar applications, technology, conferences and new products. Published monthly. $28.50 per year.

D-4: *Alternative Sources of Energy Newsletter*
Rt. 2, Box 90-A
Milaca, MN 56353

Information exchange and source of continuing information on all aspects of renewable energy sources. Do-it-yourself orientation. Published four times a year. $6.00 per year.

D-5: *Solar Energy*
Subscription Fulfillment Manager
Headington Hill Hall
Oxford OX3 OBW, England

The official journal of the International Solar Energy Society, devoted exclusively to the science and technology of solar energy applications. Research oriented, so interesting but of limited use to the do-it-yourselfer. $71 per year, free to members of ISES.

E. Do-It-Yourself and Construction

Plans and other instruction materials for people who want to do their own work are becoming increasingly available. Here's the best of the plans we're familiar with, along with some more general construction material to help you build your own solar energy system.

E-1: Zomeworks Corporation
P. O. Box 712
Albuquerque, NM 87103

Zomeworks publishes plans for:
- Thermosiphon water heater with flat plate collector and simple heat exchanger, $5.00.
- Breadbox water heater, $2.50.
- Drum wall, $5.00.

Write for their complete list.

E-2: Horace McCracken
Solar Energy Consultant
Rt. 1, Box 417
Alpine, CA 92001

"How to Build a Passive System Solar Water Heater." 1976, 17 pp.

Instructions, material list, and plans for construction of a breadbox water heater requiring no insulated doors. Contains performance data.

E-3: *Rain Magazine*
2270 N. W. Irving
Portland, OR 97210

Solar Workshop Manual, Ken Smith, Lee Johnson, Rollin Francisco. 1977. $3.

Step-by-step, photo-illustrated instructions, material and tool lists, and plans for a do-it-yourself solar water heating system adaptable to existing home water heaters.

E-4: Brace Research Institute
McDonald College of McGill University
Ste. Anne de Bellevue
Quebec, Canada H9X 3M1

"How to Build a Solar Water Heater." 10 pp.

Leaflet describing how to build a simple, low-cost thermosiphon water heating system using galvanized steel pipe and corrugated sheet metal.
Write for their complete list.

E-5: Copper Development Association, Inc.
405 Lexington Avenue
New York, NY 10017

"How to Design and Build a Solar Swimming Pool Heater." Francis de Winter. 1975. 46 pp. Free.

Gives detailed instructions for building a glazed or unglazed copper swimming pool collector. Covers engineering and economics as well as construction.

E-6: Edmund Scientific Co.
555 Edscorp Bldg.
Barrington, NJ 08007

The Edmund catalog contains a number of interesting solar items. Write for it.

E-7: Burns, Al. *The Skylight Book.* Philadelphia: Running Press, 1976. 111 pp. $5.00.

Step-by-step instructions on how to install home-made and prefabricated skylights on existing buildings. Double-glazed skylights are included. Lots of photographs showing design ideas for using skylights.

E-8: Kern, Ken. *The Owner-Built Home.* New York: Charles Scribners Sons, 1972. 374 pp. $6.95.

Extensive information on how to design and build functional, energy-efficient, yet inexpensive structures. A variety of materials and construction techniques are discussed.

E-9: Day, Richard. *The Practical Handbook of Plumbing and Heating.* New York: Arco Publishing Co., 1969. 128 pp. $4.95.

Enough practical information to handle most home plumbing jobs. Provides a thorough introduction to the most critical skill involved in installing a solar water heating system. Good information on conventional space heating systems as well. Good photographs and diagrams.

E-10: Wagner, Willis H. *Modern Carpentry.* South Holland, IL: Goodheart-Willcox Co., 1973. 480 pp. About $10.00.

Basic information on building materials and construction tools and methods. Drawings and photographs show typical house construction details, from foundation to roof. Used by many union apprenticeship programs.

See also: B-6

Appendix 1

Performance Chart Methods and Sources of Error

There are three major classes of errors which could cause the performance estimates given in Chapter 5 to differ from the performance of the systems people will build:

- Failure of our calculations and computer model to accurately represent the performance of the system modeled under the conditions assumed.
- Failure of our assumptions to match the conditions under which the real system operates.
- Construction of a solar system significantly different from the one modeled.

The following explanation of methodology includes a discussion of each type of error.

Modeling techniques

Modeling of solar heating systems was done using the SUN computer program developed by Berkeley Solar Group. The program uses a statistical radiation model based on the work of Liu and Jordan [1] and a collector model based on work by Whillier [2] and Duffie and Beckman [3]. Heating loads are based on monthly degree days. The program models one average day each month and calculates the long term average performance of the system using the utilizability procedure developed by Liu and Jordan. The program has been verified by comparison of results with those from SIMSHAC, developed at Colorado State University. SUN produced results within 5% to 20% of SIMSHAC. The program results have also been compared for several California sites with calculations done according to the "Simplified Method for Sizing Solar Systems" included in ERDA's *Pacific Regional Solar Heating Handbook* [4] and the results were within 10%.

Domestic water heating systems were modeled using the WTR version of SUN. Combined water and space heating systems were approximated by adding an appropriate number of heating degree days each month to the heating load input to SUN.

The major source of potential errors in the computer analysis is the possible difference between the performance of systems under average conditions and the average performance of systems under the full range of conditions encountered. Standard flat-plate collector systems with normal amounts of storage appear to be amenable to design under average conditions with acceptable results as shown by both Balcomb in [4] and Klein, Beckman, and Duffie [5]. Water walls and other types of passive solar heating systems, as well as systems without storage, are more effected by day-to-day and hour-to-hour weather patterns. In addition, relatively little analytic and experimental work has been done on these systems and no widely accepted performance models exist for them.

The computer methodology used was chosen because it is capable of producing performance estimates at a relatively low cost using the minimal climate data which are available. Results are felt to be within 5% for the conventional flat-plate systems and are approximately correct for the other systems, although it has not been possible to verify this.

Operating condition assumptions

Annual heating and water heating loads are estimated in Chapter 2 directly from utility bills. This method was chosen in order to avoid tedious and complicated heat loss calculations and also to avoid a major source of error. It has been shown that heating energy consumption varies up to 50% in a group of identical houses. By using actual consumption records, heating needs can be estimated for the particular situation quite easily and accurately.

The month-by-month pattern of heating loads was assumed to be proportional to the month-by-month pattern of long-term monthly average degree days. Climate zones were derived by selecting areas with nearly identical patterns of normalized degree days. Potential errors here include micro-climate variations within a zone not represented by published data, altitude effects, and differences in personal patterns. It is ironic that one of the most effective conservation measures recommended – reduced night thermostat settings – will tend to cause a systematic error in the performance estimation procedure by reducing heating needs relatively more in mild weather than in mid-winter. This would alter the pattern of heating loads predicted by the degree day model and cause the % Solar to be over estimated by the Performance Charts.

Radiation data were obtained from the sources listed in Appendix 2. Most authorities consider 10 years of data to be acceptable for establishing average solar radiation, so there is some probability of error because of the short records at almost all of the Bay Area stations.

After a set of preliminary runs using all available data, the two extreme sites in each Climate Zone were modeled, except in zones 3, 4, and 5 where data were available for Redwood City, Napa, and Livermore only. The results from the two extreme stations in each zone were averaged to get the Performance Chart curves presented in Chapter 5.

Local radiation variations due to fog or clouds could cause significant errors in the analysis. A more severe problem is caused by annual variations in both radiation and degree days. Performance estimates are for long term average conditions, but any particular year can vary by 25% or more from the average. The performance predicted should not be expected in any particular year.

Shortly before the completion of *Solar for Your Present Home*, the Lawrence Berkeley Laboratory released the *California Solar Data Manual* [6]. This book presents rehabilitated solar radiation data for many locations throughout the State, including those in the Bay Area. The data were corrected to account for inaccurate calibration of instruments and, in some cases, data that appeared unreliable were deleted. Appendix 2 lists corrected radiation data as well as raw data. Note that data were deleted for Napa and Livermore. Since the Performance Charts for Climate Zones 4 and 5 are based on these data, those charts should be regarded as less reliable than those for the other zones. Radiation data for other locations were corrected as much as 18% on a monthly basis; however, most of the corrections were less than 10%. Work at Lawrence Berkeley Laboratory suggests that, in most cases, radiation data errors produce errors about half as large in performance estimates (e.g., a 10% radiation data error causes a 5% error in the performance estimate) [7]. This would indicate that a 5% to 10% error in the Performance Charts would be the maximum inaccuracy expected.

Systems modeled

The solar systems modeled are typical systems for retrofit application and relevant specifications are described in the Representative System Table in Chapter 5. Where possible we have used the specifications for the Standard Systems as outlined in ERDA's *Pacific Regional Solar Heating Handbook*. Any real system will differ in some respects from the model; many will be significantly different because of their particular situations. System performance may be altered by changes in the specifications of components and design parameters. The ERDA handbook contains parameter studies for some critical elements, but it is impossible to imagine, let alone model, all possible variations. Professional designers and technically inclined readers are referred to the ERDA handbook and the other technical references for information on the effects of system variations.

The Performance Charts are based on data from the following locations:

Zone	Degree Days	Temperature	Radiation
1	Fort Ross	Fort Ross	Muir Beach/ Bennett Maps
	San Francisco Fed. Building	San Francisco Fed. Building	San Francisco Fed. Building
2	San Leandro	San Leandro	Fremont
	Richmond	Richmond	Richmond
3	Redwood City	Redwood City	Redwood City
4	Napa	Napa	Napa
5	Livermore	Livermore	Livermore
6	Davis	Davis	Davis
	Antioch	Antioch	Pittsburg

References

1. Benjamin Y.H. Liu, and Richard C. Jordan, "Availability of Solar Energy for Flat-Plate Solar Heat Collectors." *Low Temperature Engineering Application of Solar Energy.* 1964-66 Technical Committee on Solar Energy Utilization, American Society of Heating, Refrigerating and Air-Conditioning Engineers.
2. Austin Whillier, "Design Factors Influencing Collector Performance." *Low-Temperature Engineering Application of Solar energy.* 1964-66 Technical Committee on Solar Energy Utilization, American Society of Heating, Refrigerating, and Air-Conditioning Engineers.
3. John A. Duffie, and William A. Beckman, *Solar Energy Thermal Processes.* New York, N.Y., John Wiley & Sons, 1974.
4. Los Alamos Scientific Laboratory, *Pacific Regional Solar Heating Handbook,* by J.D. Balcomb et al. for ERDA San Francisco Operations Office. U.S. Government Printing Office, Nov. 1976.
5. S.A. Klein, W.A. Beckman, and J.A. Duffie, "A Design Procedure for Solar Heating Systems." *Solar Energy,* Vol. 18 No. 2, 1976.
6. P. Berdahl, D. Grether, M. Martin, and M. Wahlig, *California Solar Data Manual.* University of California, Lawrence Berkeley Laboratory, 1977.
7. P. Berdahl, D. Grether, M. Martin, and M. Wahlig, *Analysis of the California Solar Resource: Final Report.* University of California, Lawrence Berkeley Laboratory Report No. LBL-5972, 1977.

Location	S[1]	Per[2]	Yr[3]	Average monthly degree days												
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Antioch	1	41-70	30	598	406	347	200	76	23	0	0	7	76	333	561	2627
Berkeley	1	41-70	30	487	358	353	282	214	137	118	100	77	125	276	446	2973
Cloverdale	1	41-70	30	558	400	372	254	108	27	0	0	11	100	312	524	2666
Davis	1	41-70	30	620	431	378	230	92	19	0	0	9	97	354	589	2819
Fort Ross	2	66-75	10	506	420	454	439	367	282	253	231	189	264	348	498	4251
Gilroy	2	66-75	10	558	395	342	268	116	32	2	2	20	128	324	572	2762
Graton	1	41-70	30	608	448	434	321	204	93	41	42	64	185	390	583	3413
Half Moon Bay	1	41-70	30	468	392	425	378	322	252	229	216	186	245	315	431	3859
Healdsburg	1	41-70	30	558	389	357	246	111	43	8	15	19	109	318	527	2700
Kentfield	1	41-70	30	580	414	391	275	170	72	31	44	47	153	357	543	3077
Livermore	1	41-70	30	601	451	419	277	151	59	6	12	17	118	360	564	3035
Los Gatos	1	41-70	30	536	406	372	262	138	62	23	20	20	126	324	505	2794
Martinez	2	66-75	10	570	393	315	226	94	22	2	2	14	102	317	573	2631
Mt. Hamilton	1	41-70	30	747	652	713	544	368	208	38	67	77	272	506	676	4868
Napa St. Hosp.	1	41-70	30	546	386	369	270	151	64	15	17	27	110	309	505	2769
Oakland	1	41-70	30	508	367	350	270	193	114	80	74	59	135	291	468	2909
Palo Alto	1	41-70	30	549	400	378	271	164	74	34	33	57	149	342	518	2969
Petaluma	1	41-70	30	561	406	394	300	189	78	18	19	23	115	333	530	2966
Redwood City	1	41-70	30	515	375	344	239	124	47	15	13	23	118	306	477	2596
Richmond	2	66-75	10	477	334	304	250	172	108	94	69	47	104	254	484	2697
St. Helena	1	41-70	30	592	428	406	273	126	36	0	0	14	131	357	555	2918
St. Mary's Col.	2	66-75	10	652	483	433	351	175	85	29	17	41	197	418	665	3540
S.F. Airport	1	41-70	30	518	386	372	291	210	120	93	84	66	137	291	474	3042
S.F. Fed. Bldg.	1	41-70	30	437	325	332	291	257	194	202	177	102	127	233	403	3080
S.F. Richmond	2	66-75	10	446	354	364	356	308	243	218	193	149	187	286	446	3550
San Gregorio	2	66-75	10	501	401	434	411	323	226	184	157	143	257	348	514	3899
San Jose	1	41-70	30	481	350	322	228	123	50	12	15	13	90	276	456	2416
Upper S. Leandro	2	66-75	10	538	408	398	350	243	151	87	61	68	161	331	536	3332
San Mateo	1	41-70	30	481	353	338	254	166	85	42	47	41	123	279	446	2655
Santa Cruz	1	41-70	30	502	392	391	309	219	128	88	83	80	164	315	468	3139
Santa Rosa	1	41-70	30	586	420	406	289	171	78	20	22	33	134	354	552	3065
Vacaville	1	41-70	30	620	426	366	234	87	23	0	0	0	107	357	592	2812
Walnut Creek	2	66-75	9	589	426	352	273	121	37	5	4	27	155	346	590	2916
Watsonville	1	41-70	30	515	400	403	315	251	170	138	137	112	182	318	477	3418

Raw data

Location	S[1]	Per[2]	Yr[3]	Average daily radiation on a horizontal surface (BTU per sq. ft.) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Burlingame	3	71-76	3	777	988	1422	1876	2262	2356	2300	2032	1577	1153	790	662
Davis	4			599	945	1504	1959	2369	2619	2566	2288	1857	1289	796	551
Fremont	3	70-76	6	822	1088	1408	1921	2234	2448	2360	2046	1644	1283	819	645
Livermore	3	71-73	3	852	988	1670	2113	2293	2574	2533	2352	1914	1349	870	719
Napa	3	72-74	3	627	880	1284	1586	2159	2231	2182	1972	1601	1003	625	542
Pittsburg	3	70-74	4	608	993	1485	2077	2398	2517	2586	2357	1831	1278	636	511
Redwood City	3	70-74	4	681	1034	1405	2021	2234	2393	2362	2115	1730	1194	778	591
Richmond	3	70-74	5	694	879	1263	1678	1804	1967	1911	1721	1436	971	632	569
San Francisco	3	70-74	4	660	959	1405	1829	2009	2209	2002	1766	1600	1091	675	512
San Jose	3	70-75	6	706	960	1377	1898	2096	2276	2249	2062	1673	1178	764	579
San Rafael	3	70-74	4	587	892	1261	1816	2035	2213	2200	1987	1589	1046	635	494
Vallejo	3	72-74	2	618	903	1272	2175	2269	2373	2266	1993	1600	1143	724	571
Zone 1	5			613	824	1124	1823	1871	1968	1743	1519	1347	1056	659	541

Corrected data (see page 122)

Burlingame	–			Data deleted											
Davis	4			645	893	1419	1933	2323	2533	2548	2260	1830	1290	800	581
Fremont	3	70-76	2	808	1011	1435	1898	2002	2291	2243	2094	1803	1296	814	643
Livermore	–			Data deleted											
Napa	–			Data deleted											
Pittsburg	3	70-74	3	602	969	1445	2012	2325	2439	2503	2284	1850	1217	656	478
Redwood City	3	70-76	5	787	1055	1489	2069	2354	2484	2439	2126	1796	1248	830	640
Richmond	3	70-74	4	725	1036	1448	1932	2081	2265	2201	1980	1657	1118	716	627
San Francisco	3	70-76	2	776	1004	1480	1936	1942	2104	1936	1765	1733	1194	697	513
San Jose	3	70-76	5	754	1011	1461	2024	2234	2433	2405	2135	1787	1258	817	637
San Rafael	3	70-76	4	684	1011	1432	2047	2297	2497	2481	2240	1790	1179	713	554
Vallejo	3	72-74	2	599	878	1236	2116	2208	2306	2205	1939	1556	1109	703	551

Notes

1. S: Source of data
   1. U.S. Department of Commerce, "Monthly Normals of Temperature, Precipitation, and Heating and Cooling Degree-Days 1941-70," *Climatography of the United States No. 81* (California); National Climatic Center, Asheville, N.C.
   2. Calculated from 10 years of data (1966-1975) from *Climatological Data of California*, National Weather Records Center, Asheville, N.C.
   3. Bay Area Air Pollution Control District
   4. U.S. Weather Bureau Long-term Average
   5. Compiled from data recorded by PG&E at Muir Beach, April 1973 to March 1974, and Bennett, Iven, "Monthly Maps of Mean Daily Insolation for the United States," *Solar Energy* 1965, Vol. 9, No. 3, pp. 145-160.
2. Per: Observation period
3. Yr: Length of record in years

Appendix 3:

Existing Bay Area Retrofits

As of September 1976

Function(s) Provided[1]	Type of System[2]	Size (ft^2)	Total Cost	Cost per sq. ft.	Built by[3]	Financing
1. DHW	A	26	$ 500	$19.23	O	Self
2. DHW	A	50	1,000	20.00	C	Self
3. DHW	A	86	1,060	12.33	O	Self
4. DHW	A	50	1,400	28.00	C	Self
5. DHW	A	70	2,800	40.00	O	Self
6. DHW	A	15	50	3.33	O	Self
7. DHW	A	56	2,060	36.80	C	Self
8. SH	B	288	900	3.15	O	Self
9. SH	D	120	500	4.15	O	Grant
10. SH, SC	E	200	500	2.50	O	Bank
11. DHW, SH	B	400	1,100	2.75	O	Self
12. DHW, SH	C	640	5,670	8.85	C	Self
13. DHW, SH	C	338	3,000	8.90	C	Self
14. DHW, SH	C	230	3,260	14.15	O	Self
15. DHW, SH	C	381	6,000	15.75	C	Credit Union
16. DHW, SH, Pool	C	385	2,900	7.55	O	Credit Union
17. DHW, SH, Pool	C	533	2,100	3.95	O	Self
18. DHW, SH, Pool	C	540	8,000	14.81	C	Bank

Notes:

1. DHW - domestic hot water
   SH - space heating
   SC - space cooling
   Pool - pool heating
2. A - flat-plate collector. Numbers 1, 3, and 6 are thermosiphon systems, the rest are pumped.
   B - active system, trickle type.
   C - active system, tube and plate water type.
   D - passive system, greenhouse air heater.
   E - passive system, drum wall and concrete slab floor.
3. O - built by the owner.
   C - built by a contractor or someone other than the owner.

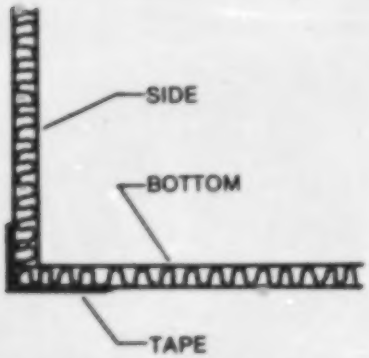
How to Make the Solar Viewer

What you will need:

1. Heavy cardboard (one carton should do it)
2. A knife or heavy scissors for cutting the cardboard
3. Heavy tape, such as Mystic Tape or masking tape
4. Transparent tape
5. Thin string (18 inches is plenty)
6. Paper clips

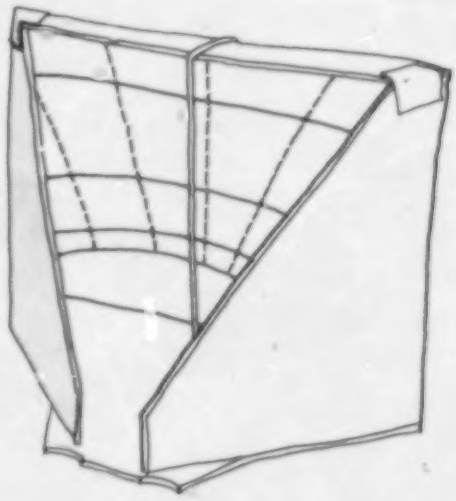
Here's what you do:

1. Remove pages 159 and 161 of this book – they are the patterns for the Viewer parts. Cut out the shapes marked TOP, BOTTOM, and SIDES along their *solid* outlines.
2. Cut out the cardboard pieces according to the labeled patterns. Don't forget to make the hole in the bottom piece. It should be made accurately, since it will be the "level indicator" for the Viewer.
3. Assemble the pieces as indicated on the patterns. Make joints with heavy tape. The bottom pattern has dotted lines on it that indicate where the inside edge of the sides should end up, but the best approach is to line up the outside of the sides with the edge of the bottom. The joints will come out like this:



It seems to be easiest to put the tape on the bottom, get everything lined up, then stick the tape to the sides. Put the top on last.

4. Remove page 163, the transparent Sunpath Diagram, from the book. Attach it to the front of the Viewer with transparent tape. Make sure that the Diagram is the right way around. You should be able to read the numbers and words on it when you look through the Viewer.
5. Tie seven or eight paperclips to the end of the string (this makes a small weight) and thread the string up through the hole to the notch in the top. Adjust the length of the string so the top of the paperclips is only a fraction of an inch below the bottom and tape the string in place on the top. This is the level indicator.
6. Hold the Viewer with one of the curved nosepieces against your nose, at a level such that your line of sight is just even with the bottom. You'll be looking through the Viewer with just one eye. Now adjust the Viewer so the string hangs freely without touching the sides of the hole, indicating that the Viewer is level. You should be able to see most of the sunpath diagram by scanning around with your eye. If the sides block your line of vision, trim the nosepiece (or your nose) appropriately.
7. See Chapter 3, page 46, for instructions on how to use this Viewer.



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Worksheet 1:

Energy Record

	Natural Gas	Electricity	Propane	Fuel Oil
1. January	_____ therms	_____ KWH	_____ gal.	_____ gal.
2. February	_____	_____	_____	_____
3. March	_____	_____	_____	_____
4. April	_____	_____	_____	_____
5. May	_____	_____	_____	_____
6. June	_____	_____	_____	_____
7. July	_____	_____	_____	_____
8. August	_____	_____	_____	_____
9. September	_____	_____	_____	_____
10. October	_____	_____	_____	_____
11. November	_____	_____	_____	_____
12. December	_____	_____	_____	_____
13. Total	_____ therms	_____ KWH	_____ gal.	_____ gal.
14. Conversion factor	× 1.0	× .034	× .92	× 1.4
15. Total Annual Energy Use	_____ therms	_____ therms	_____ therms	_____ therms

Worksheet 2:

Energy Use for Space Heating with Natural Gas
No Summer Space Heating

1. *Enter your natural gas* Total Annual Energy Use *from Line 15 of your Energy Record (Worksheet 1).* _____ (1)

2. a. *Enter the number of therms you used during each month you did not use your furnace.*

   May _____

   June _____

   July _____

   Aug _____

   Sept _____

   Oct _____

   Total _____ (2a)

   b. *Divide the total by the number of months you did not use your furnace to get your average monthly energy use for the months you did no space heating.*

   _____ (2a) ÷ _____ Number of months = _____ (2b)

   c. *Multiply Line 2b by 12.*

   _____ (2b) × 12 = _____ (2c)

3. *Subtract Line 2c from Line 1.* _____ (3)

4. Burner efficiency correction: Only 70% of the heat from the gas actually warms your house (the rest goes up the flue). *Multiply Line 3 by .7 to get your* Net Energy Use for Space Heating.

   _____ (3) × .7 = _____ (4)

Transfer Line 4 to Worksheet 6, Line 5.

Worksheet 3:

Energy Use for Water Heating with Natural Gas
No Summer Space Heating

Worksheet 2 must be completed first.

1. *Enter result from Line 2c of Worksheet 2.* _____ (1)

2. Adjustments for other uses of gas:

   a. Cooking:

   Enter 100 for gas stove with pilot lights
   60 for gas stove without pilot lights
   0 for non-gas stove _____ (2a)

   b. Clothes drying:

   If you have a gas dryer, calculate your energy use as follows: 20 × _____ (Number of people in household) = _____ (2b)

   c. Other uses:

   Estimate your gas consumption for other uses such as barbecues or outdoor lighting. Your utility can help you with this. Enter the total therms per year. _____ (2c)

   d. *Add Lines 2a, 2b, and 2c.* _____ (2d)

3. *Subtract Line 2d from Line 1.* _____ (3)

4. Furnace pilot light correction. Your furnace pilot light consumes about 7 therms each month that it burns. *Enter the number of months per year your pilot light is on (some people turn it off during the summer) and multiply by 7.* _____ (Number of months) × 7 = _____ (4)

5. *Subtract Line 4 from Line 3.* _____ (5)

6. Standby loss correction: Your water heater wastes about 120 therms per year due to tank heat losses. *Subtract 120 from Line 5.* _____ (5) − 120 = _____ (6)

7. Burner inefficiency correction: Only 70% of the heat from the burning gas actually warms your water. *Multiply Line 6 by .7 to get your* Net Energy Use for Water Heating. _____ (6) × .7 = _____ (7)

Transfer Line 7 to Worksheet 6, Line 1.

Worksheet 4:

Energy Use for Space Heating with Natural Gas Space Heating All Year

1. *Enter your natural gas* Total Annual Energy Use *from Line 15 of your Energy Record (Worksheet 1).* _____ (1)

2. Adjustments for other uses of gas:

   a. Cooking:

   Enter 100 for gas stove with pilot lights
   80 for gas stove without pilot lights
   0 for non-gas stove _____ (2a)

   b. Clothes drying:

   If you have a gas dryer, calculate your energy use as follows: 20 × _____ (Number of people in household) = _____ (2b)

   c. Other uses:

   Estimate your gas consumption for other uses such as barbeques or outdoor lighting. Your utility can help you with this. Enter the total therms per year. _____ (2c)

   d. *Add Lines 2a, 2b, and 2c.* _____ (2d)

3. *Subtract Line 2d from Line 1.* _____ (3)

4. Furnace pilot light correction. Your furnace pilot light consumes about 7 therms each month that it burns. *Enter the number of months per year your pilot light is on (some people turn it off during the summer) and multiply by 7.* _____ (Number of months) × 7 = _____ (4)

5. *Subtract Line 4 from Line 3.* _____ (5)

6. Burner efficiency correction: Only 70% of the heat from the gas actually warms your house (the rest goes up the flue). *Multiply Line 5 by .7 to get your* Net Energy Use for Space Heating. _____ (5) × .7 = _____ (6)

Transfer Line 6 to Worksheet 6, Line 5.

Worksheet 5:

Energy Use for Space and Water Heating with Natural Gas Space Heating All Year

1. *Enter your natural gas* Total Annual Energy Use *from Line 15 of your Energy Record (Worksheet 1).* _____ (1)

2. Adjustments for other uses of gas:

   a. Cooking:
   Enter 100 for gas stove with pilot lights
   60 for gas stove without pilot lights
   0 for non-gas stove _____ (2a)

   b. Clothes drying:
   If you have a gas dryer, calculate your energy use as follows:
   20 × _____ (Number of people in household) = _____ (2b)

   c. Other Uses:
   Estimate your gas consumption for other uses such as barbecues or outdoor lighting. Your utility can help you with this. Enter the total therms per year. _____ (2c)

   d. *Add Lines 2a, 2b, and 2c.* _____ (2d)

3. *Subtract Line 2d from Line 1.* _____ (3)

4. *Enter your estimated Natural Gas Use for Water Heating from Column B of Table 2-1 (page 30).* _____ (4)

5. *Subtract Line 4 from Line 3* _____ (5)

6. Furnace pilot light correction. Your furnace pilot light consumes about 7 therms each month that it burns. *Enter the number of months per year your pilot light is on (some people turn it off during the summer) and multiply by 7.*
   _____ (Number of months) × 7 = _____ (6)

7. *Subtract Line 6 from Line 5.* _____ (7)

8. Burner efficiency correction: Only 70% of the heat from the gas actually warms your house (the rest goes up the flue). *Multiply Line 7 by .7 to get your* Net Energy Use for Space Heating.
   _____ (7) × .7 = _____ (8)

9. *Enter your estimated* Net Energy Use for Water Heating *from Column A of Table 2-1 (page 30).* _____ (9)

Transfer Lines 8 and 9 to Worksheet 6, Lines 5 and 1.

Worksheet 6:

Reducing the Energy Used for Water Heating and Space Heating

Water Heating

1. Net Energy Use for Water Heating _____ (1)

2. Energy conservation measures

	Energy use reduction	
a. Reduce hot water use	_____ (2a)	
b. Fix hot water leaks	_____ (2b)	
c. Total		_____ (2c)

3. *Multiply Line 2c times Line 1.* _____ (3)

4. *Subtract Line 3 from Line 1 to determine your* Annual Energy Demand for Water Heating. _____ (4)

Space Heating

5. Net Energy Use for Space Heating _____ (5)

6. Energy conservation measures

		Energy use reduction		Energy use remaining	
a. Lower thermostat	1.00	– _____	=	_____	(6a)
b. Stop air leaks	1.00	– _____	=	_____	(6b)
c. Insulate ceiling	1.00	– _____	=	_____	(6c)
d. Insulate walls	1.00	– _____	=	_____	(6d)
e. Insulate windows	1.00	– _____	=	_____	(6e)

7. _____ (6a) × _____ (6b) × _____ (6c) × _____ (6d) × _____ (6e) = _____ (7)

8. *Multiply Line 7 times Line 5 to determine your* Annual Energy Demand for Space Heating. _____ (8)

Worksheet 7: Solar Prospecting

	Surface 1	Surface 2	Surface 3	Surface 4
1. Location and type				
2. Orientation				
3. Slope				
4. Obstructions on surface				
5. Shading of surface				
6. *Enter length and width of unobstructed, unshaded area.*	×	×	×	×
7. *Multiply to get gross area.*				
8. *Enter Free-standing Factor.*				
9. *Multiply to get Usable Area.*				
10. *Enter Orientation/Frame Factor.*				
11. *Multiply to get Effective Area.*				
12. Existing equipment				
12a. Water heater type and location				
12b. Furnace type and location				

Worksheet 8:

Performance Estimating

Climate zone: _____

A. Surface Location and Slope	B. Chart	C. Curve	D. Effective Area (sq. ft.)	E. Trial Area (sq. ft.)	F. Annual Energy Demand (therms)	G. CLR	H. % Solar	I. Annual Energy Saving (therms)	J. Orientation/ Frame Factor	K. Installed Area (sq. ft.)

Worksheet 9:

Initial Cost ; Loan Payments; State Income Tax Credit

Initial Cost

1. Design cost — $ _____ (1)
2. Permits and approvals cost — $ _____ (2)
3. Installation Cost:

   _____ (cost per sq. ft. (Chapter 4)) × _____ (Installed Area (Chapter 5)) = $ _____ (3)
4. Total System Cost: *Add Lines 1, 2, and 3.* — $ _____ (4)
5. Money borrowed (less any loan fees) — $ _____ (5)
6. Initial Cost: *Subtract Line 5 from Line 4.* — $ _____ (6)
7. Loan Payments (from Table 6-1) — $ _____ (7)

State Income Tax Credit (for active systems only)

8. 55% of Total System Cost

   _____ (4) × .55 = $ _____ (8)
9. Tax Credit

   Enter the smaller of Line 8 and $3000. — $ _____ (9)

Worksheet 10:

Operating and Maintenance Costs

A. Installation Cost (Worksheet 9)		B. Operating and Maintenance Factor		C.		D. Inflation Factor		E. Operating and Maintenance Costs	F. Year
_____	×	_____	=	_____	×	1.00	=	_____	1
					×	1.06	=	_____	2
		Operating and Maintenance Factors			×	1.12	=	_____	3
		Active systems	.02		×	1.19	=	_____	4
		Passive systems	.01		×	1.26	=	_____	5
					×	1.34	=	_____	6
					×	1.42	=	_____	7
					×	1.50	=	_____	8
					×	1.59	=	_____	9
					×	1.69	=	_____	10
					×	1.79	=	_____	11
					×	1.90	=	_____	12
					×	2.01	=	_____	13
					×	2.13	=	_____	14
					×	2.26	=	_____	15
					×	2.39	=	_____	16
					×	2.54	=	_____	17
					×	2.69	=	_____	18
					×	2.85	=	_____	19
					×	3.03	=	_____	20

Worksheet 11:

Savings

Type of fuel: _____

A. Energy Cost		B. Conversion Factor		C.		D. Energy Saving (Worksheet 8)		E.		F. Fuel Inflation Factor (Table 6-2)		G. Saving	H. Year
_____	×	_____	=	_____	×	_____	=	_____	×	1.00	=	_____	1
									×	_____	=	_____	2
									×	_____	=	_____	3
									×	_____	=	_____	4
									×	_____	=	_____	5
									×	_____	=	_____	6
									×	_____	=	_____	7
									×	_____	=	_____	8
									×	_____	=	_____	9
									×	_____	=	_____	10
									×	_____	=	_____	11
									×	_____	=	_____	12
									×	_____	=	_____	13
									×	_____	=	_____	14
									×	_____	=	_____	15
									×	_____	=	_____	16
									×	_____	=	_____	17
									×	_____	=	_____	18
									×	_____	=	_____	19
									×	_____	=	_____	20

Conversion Factors	
Natural gas	1.4
Electricity	29
Propane	1.5
Fuel oil	1.2

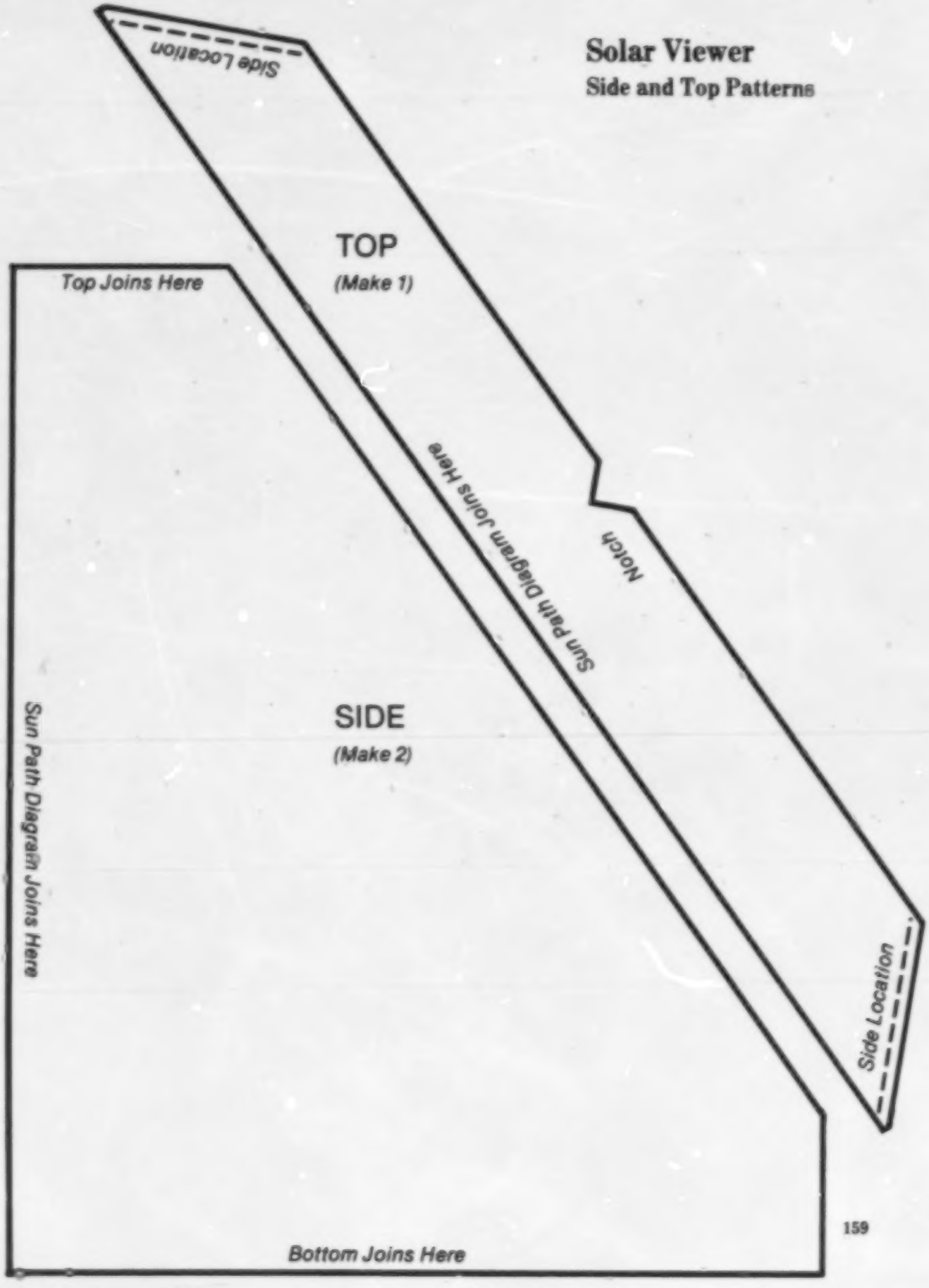
Worksheet 12:

Net Costs and Savings

A. Yr	B. Initial Cost	C. Loan Payments	D. Operating and Maintenance Costs	E. Total Costs	F. Savings	G. Net Cost (–) or Saving (+) (Inflated $)	H. Inflation Factor	I. Net Cost (–) or Saving (+) (Present $)	J. Discount Factor	K. Present Value
1	_____ +	_____ +	_____ =	_____						
		Tax Credit (Worksheet 9) –		_____						
				_____	_____	_____ ×	.94 =	_____ ×	_____ =	_____
2		_____ +	_____ =	_____	_____	_____ ×	.89 =	_____ ×	_____ =	_____
3		_____ +	_____ =	_____	_____	_____ ×	.84 =	_____ ×	_____ =	_____
4		_____ +	_____ =	_____	_____	_____ ×	.79 =	_____ ×	_____ =	_____
5		_____ +	_____ =	_____	_____	_____ ×	.75 =	_____ ×	_____ =	_____
6		_____ +	_____ =	_____	_____	_____ ×	.70 =	_____ ×	_____ =	_____
7		_____ +	_____ =	_____	_____	_____ ×	.67 =	_____ ×	_____ =	_____
8		_____ +	_____ =	_____	_____	_____ ×	.63 =	_____ ×	_____ =	_____
9		_____ +	_____ =	_____	_____	_____ ×	.59 =	_____ ×	_____ =	_____
10		_____ +	_____ =	_____	_____	_____ ×	.56 =	_____ ×	_____ =	_____
11		_____ +	_____ =	_____	_____	_____ ×	.53 =	_____ ×	_____ =	_____
12		_____ +	_____ =	_____	_____	_____ ×	.50 =	_____ ×	_____ =	_____
13		_____ +	_____ =	_____	_____	_____ ×	.47 =	_____ ×	_____ =	_____
14		_____ +	_____ =	_____	_____	_____ ×	.44 =	_____ ×	_____ =	_____
15		_____ +	_____ =	_____	_____	_____ ×	.42 =	_____ ×	_____ =	_____
16		_____ +	_____ =	_____	_____	_____ ×	.39 =	_____ ×	_____ =	_____
17		_____ +	_____ =	_____	_____	_____ ×	.37 =	_____ ×	_____ =	_____
18		_____ +	_____ =	_____	_____	_____ ×	.35 =	_____ ×	_____ =	_____
19		_____ +	_____ =	_____	_____	_____ ×	.33 =	_____ ×	_____ =	_____
20		_____ +	_____ =	_____	_____	_____ ×	.31 =	_____ ×	_____ =	_____
						Cost (–) or Saving (+) (inflated $)		Cost (–) or Saving (+) (present $)		Life-Cycle Cost or Saving

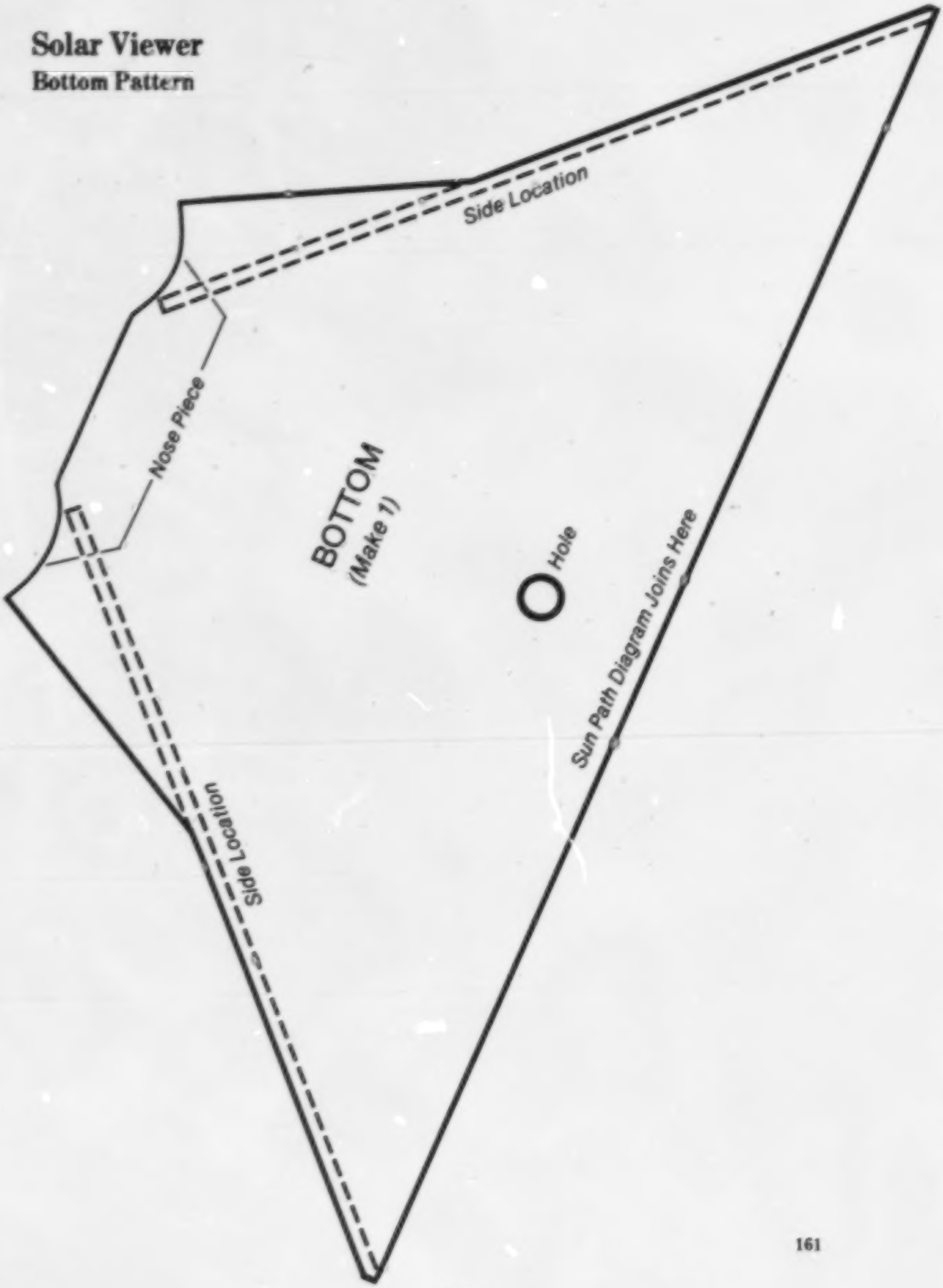
Solar Viewer

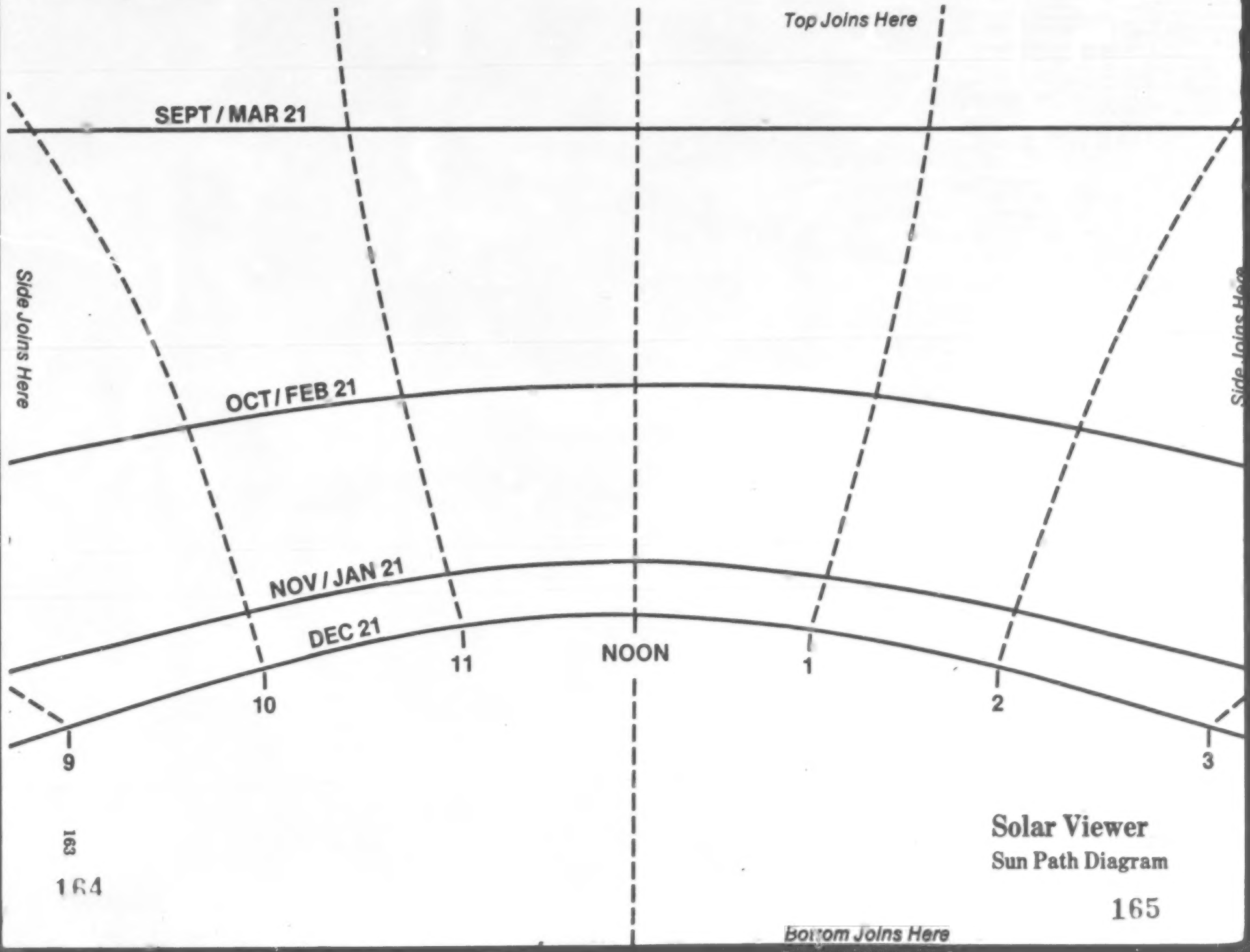
Side and Top Patterns



Solar Viewer

Bottom Pattern





Solar Viewer

Sun Path Diagram